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ST. LAWRENCE RIVER ENVIRONMENTAL INVESTIGATIONS

VOLUME 1

BACKGROUND: ASSESSMENT OF WATER, SEDIMENT AND BIOTA IN THE CORNWALL, ONTARIO AND MASSENA, NEW YORK SECTION OF THE ST. LAWRENCE RIVER 1979-1982

FEBRUARY 1988

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Environment Ontario
Jim Bradley
Minister

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BACKGROUND: ASSESSMENT OF WATER, SEDIMENT AND BIOTA IN THE CORNWALL, ONTARIO AND MASSENA, NEW YORK SECTION OF THE ST. LAWRENCE RIVER 1979-1982

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FOREWORD

The findings and recommendations in this report are based on investigations conducted during 1979, 1980 and 1982 and reflect inputs to, and the water quality status of the Cornwall-Massena section of the St. Lawrence River at that time. The report therefore provides a basis for comparison with data on loadings, water, sediment and biota after remedial measures have been implemented and fully realized.

Many of the report's findings were conveyed at an early stage to the Ontario Ministry of Environment's Southeastern Region and Cornwall District Offices and to other concerned agencies such as the International Joint Commission (see IJC, 1982), Environment Canada and the New York State Department of Environmental Conservation (NYSDEC), and a number of follow-up studies were undertaken to address concerns or data gaps. In addition, a number of other studies have been underway in this area, based on problems identified by other studies or the priorities of individual agencies. The following summarizes these studies in relation to the numbered recommendations:

1. As a follow-up to Recommendation 1 regarding the detection of high total phenols (phenolics) in the Domtar Fine Paper effluent, samples of the final clarifier effluent were collected during November, 1982 and analyzed for individual phenol compounds by high pressure liquid chromatography in MOE's Rexdale laboratory. These analyses did not detect (at a method detection limit of 50 ng/L) any phenolic compounds. However, a subsequent MOE survey during June, 1985 detected homovanillic acid, phenol, guaiacol and acetovanillon in the combined Domtar - CIL effluent. Phenol, vanillin, guaiacol and acetovanillon were found in river water samples taken from 0 to 1.4 km downstream of the diffusor.

   Furthermore, in response to questions regarding the application of the current Provincial Water Quality Objective (PWQO) for total phenols (1 ug/L), an ad hoc MOE working group was struck. It's report, "The Significance of Phenolic Compounds in Ontario's Waters" (De Barros, 1984) concluded that, depending on the nature of individual phenolic compounds, the existing PWQO may be either too stringent or too lenient and it is therefore of limited value.

Consequently, to effectively evaluate the potential environmental effects of phenolics, it is necessary to identify the speciated phenolic compounds. Also, as recommended by the group, PWQO's have been set for a number of individual phenolic compounds, some based on tainting thresholds (monochlorophenols, 7 ug/L; dichlorophenols, 0.2 ug/L) and others based on acute toxicity (trichlorophenols, 18 ug/L; tetrachlorophenols, 1 ug/L; pentachlorophenol, 0.5 ug/L) (McKee et al., 1984).

2. In 1983, Domtar instituted modifications to the ports of their diffusor to improve the dispersion and dilution pattern of the effluent plume (Recommendation 2). A dye dilution and fish tainting study showed that these changes resulted in moving the effluent plume further from shore and into deeper water, thus improving the aesthetic appearance. However, they also caused the effluent to be more concentrated, particularly within 200 m. downstream of the diffuser. For example, at 45 m. downstream of the diffusor, 12% of the river (north channel) volume contained effluent concentrations above the tainting threshold; at 200 m. below the diffusor, less than 4% of the river's volume was affected (Domtar Research, 1983).

3. With regard to Recommendation 3, MOE sampling in 1982 identified high fecal coliform densities in the final clarifier of Domtar. As a result, a pilot plant study for the control of bacteria by ultraviolet disinfection was initiated at Domtar during 1984 and found to be effective in controlling bacteria. Subsequently, however, pH control has been found to be more cost-effective. Appropriate company action will be required by MOE if Escherichia coli is present in concentrations indicating the presence of significant fecal coliform pollution in the plant.

   The detection of fecal coliform (FC) densities above the PWQO (100 organisms/100 mL) in Cornwall waters downstream of the Domtar discharge, the suspicion that these may mainly be due to the presence of Klebsiella which has been detected in high densities near other Ontario pulp and paper mill discharges, and speculation as to the health significance of this bacterium led to the formation of a committee (with MOE membership) to review this problem. A review produced for this group under contract concludes that Klebsiella in the environment is not of human health significance (Duncan, in press).

4. Expansion of the Cornwall WPCP should be completed during 1987. Additional storage capacity is being incorporated to reduce the number of bypasses to the river. In addition, the Pitt St. and Amelia St. combined sewer overflows have been stopped, which will also reduce the number of inputs of bacteria to the Cornwall waterfront (Recommendation 4).

5. PCB source trackdown in the Cornwall area (Recommendation 5) was conducted by MOE staff in 1982. However, no leaks were detected in any PCB - containing equipment and no obvious sources could be found which could explain the detection of PCBs in effluents at low levels. Subsequent sampling of effluents did not detect PCBs in Cornwall effluents.

   PCB source trackdown and river sampling has also been carried out by NYSDEC personnel in the Massena area and restrictions on the discharge of PCBs have been instituted for ALCOA, Reynolds Metals and General Motors. In 1983, the USEPA added the General Motors Central Foundry site to its list of National Priority Sites due to surface and groundwater contamination with PCBs.

6. Identification and elimination of mercury sources in Cornwall discharges (Recommendation 6) has been partially addressed. Low levels of mercury were found in some Courtaulds effluent samples and effluent controls will be required in a forthcoming Control Order for this facility.

7. Environment Canada undertook a detailed Cornwall effluent sampling program in 1981. This included analysis for metals and organics (i.e. volatiles, base neutral and acid extractables, PCBs, pesticides). This report was released in 1985. A 1985 MOE study examined the spatial distribution of contaminants in Cornwall waters in relation to inputs (Recommendation 7). This data will be included in the forthcoming report "Assessment of Water and Sediment Quality in the Cornwall Area of the St. Lawrence River, 1985".

8. With respect to Recommendation 8 a study was initiated by MOE during 1985 to derive zinc, hydrogen sulphide and carbon disulphide effluent limits for the Courtaulds discharge to the St. Lawrence River. This study utilized acute lethality tests of the effluents, an estimate of in-situ lethality and the impact of zinc discharges on water, bed sediment and biota. Recommendations have been made to Southeastern Region regarding discharge limits for each of these contaminants and these limits have been included in a proposed Control Order.

During 1986, the Government of Ontario released a policy and program statement for controlling industrial and municipal discharges to surface waters (MOE, 1986). The goal of this "Municipal and Industrial Strategy for Abatement (MISA)" is the virtual elimination of toxic contaminants in point source discharges to Ontario waterways. This will be achieved by establishing monitoring and best available technology (BAT) regulations for the municipal as well as eight major industrial sectors. This includes all of the major Cornwall point sources, i.e. Organic Chemicals (Courtaulds, BCL, Cornwall Chemicals); Pulp and Paper (Domtar); Inorganic Chemicals (CIL); and Municipal Sewage Treatment Works (Cornwall WPCP). In addition, a preliminary assessment of receiving water impacts will be required to confirm whether BAT limits are sufficient for the protection of water quality or whether, full-scale, detailed receiving water studies are required to establish more stringent effluent limits. With regard to the latter, MOE is conducting field studies at a number of pilot sites across Ontario to assess and evaluate the impact of various discharges on receiving water environments. One of these pilot sites is in the St. Lawrence River at Cornwall.

9. During 1985, the MOE undertook a survey of benthic community structure and sediment chemistry in the Cornwall-Massena area. Results will update the impact of discharges on the benthos and the status of sediment contamination since the earlier studies of 1966 and 1979, respectively (Recommendation 9). The reports, entitled "Environmental Quality Assessment of the St. Lawrence River in 1985 as Reflected by the Distribution of Benthic Invertebrate Communities" and "Assessment of Water and Sediment Quality in the Cornwall Area of the St. Lawrence River, 1985" form Volumes 2 and 4, respectively of the report series "St. Lawrence River Environmental Investigations", and are scheduled for release during 1987.

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SUMMARY OF FINDINGS

Studies carried out in 1979, 1980 and 1982 provided insight into the major issues resulting from industrial and municipal discharges from the Cornwall-Massena area to the St. Lawrence River. Industrial dischargers along the Ontario shoreline such as Domtar Fine Papers, Cornwall Chemicals, Canadian Industries Ltd., Courtaulds and BCL and those along the New York shoreline including ALCOA, Reynolds Metals Co. and General Motors Foundry have contributed to the impairment and restriction of water uses in the Cornwall-Massena area.

The major issues resulting from these studies are:

i. The 1979 and 1980 studies revealed elevated levels of phenolics in Cornwall nearshore surface waters which exceeded the Provincial and Agreement Objectives to protect against tainting of fish and taste and odour problems in water supplies (1 ug/L). During some 1980 surveys, this mixing zone extended as far as 8 km downstream of the Domtar/CIL/Cornwall Chemicals diffuser outfall. These findings corresponded quite well with the prediction of a multiple-source model using 1979 phenolics loadings data. The average phenolics loading rates from Domtar (235 kg/d in 1979; 116 kg/d in 1980) were markedly higher than the other Cornwall discharges sampled. Survey-to-survey differences in this loading in 1980 were correlated with receiving water quality. The dispersion of this load by the existing diffuser configuration was found to be inadequate due to the proximity of the diffuser ports to the shore, in shallow water.

   It is noteworthy that, despite exceedences of the phenolics objective in Ontario waters, no incidents of fish tainting or taste and odour problems in nearby water supplies were reported during the periods of study, suggesting that a large proportion of the reactive phenols present in Domtar's effluent are non-tainting in nature.

ii. During some of the 1980 and 1982 surveys, fecal coliform bacteria (FC) densities in Cornwall nearshore surface waters exceeded the Provincial objective for the protection of recreational uses (100 organisms/100 mL) for as far as 8 km downstream of the Domtar/CIL/Cornwall Chemicals combined outfall. These high densities were attributable mainly to Domtar Fine Papers, since variability of concentrations in the river during 1980 was principally related to changes in the final effluent bacterial density and flow rate of this industry. Furthermore, Domtar effluent FC densities generally exceeded those measured at other sources (i.e. CIL, Brookdale Ave. combined sewer and Cornwall WPCP) and, combined with the high flow rate from the paper mill, resulted in the major loading of this group of organisms. However, no reliable speciation data was available to indicate whether the Domtar FC inputs were of fecal (E. coli) or more natural (Klebsiella) origin.

On occasion, the Cornwall WPCP effluent also contained high FC densities, indicating inadequate disinfection of wastes. There was, however, little discernible downstream impact from the WPCP discharge.

The high FC densities observed on some 1980 and 1982 survey days in the vicinity of the Courtaulds/BCL complex indicated additional bacterial contributions in this area, perhaps from storm water runoff or combined sewer overflows.

iii. Mercury levels in surficial sediments along the Ontario shoreline of the river exceeded the MOE guideline for open water disposal of dredgeate (0.3 mg/kg) at 65% of stations sampled in 1979. Highest mercury levels were detected in sediments near the Canadian Industries Ltd. (CIL) and Courtaulds/BCL discharges. (The latter is an area of at least temporary sediment deposition). Mean concentrations immediately downstream of the CIL discharge were similar to 1970 and 1975 levels; further downstream (3 to 14 km), they were lower than those observed in 1970 and 1975. CIL, a

chlor-alkali plant which has been a major source of mercury discharges, is now in compliance with the regulations for chlor-alkali plants (0.0025 kg mercury per ton of chlorine produced per day). Mercury losses from CIL have been reduced substantially from the high of 590 kg/year in 1970 to the 23 kg/year level calculated from the 1979 study data. The cause of other discharges of mercury, such as those from the Courtaulds/BCL sewers, is unknown at present.

Data on filtered water samples from Cornwall in 1979 indicated that mercury concentrations were below the Provincial and Agreement objective of 0.2 ug/L. Nevertheless, mercury levels up to 2.4 mg/kg in suspended solids were prevalent near the sources, reflecting the significance of mercury discharges to the aquatic system.

Although mercury was also present in upstream samples, benthic biota, spottail shiners and sport fish were all affected by the Cornwall mercury discharges. Levels up to 70 ng/g, which are less than the Agreement objective of 500 ng/g for whole fish, were found in spottail shiners, while mean concentrations of 0.2 and 0.3 ng/g were detected in aquatic plants and macroinvertebrates, respectively. These levels occurred at stations where sediment mercury concentrations were also elevated. Recent levels of mercury in sport fish from downstream Lake St. Francis have shown a significant decline from levels measured in the early 1970's; however, large fish (size greater than 35 cm) of some species (walleye and northern pike) are still unsuitable for unrestricted consumption. Present trend data indicates the need for further reductions or elimination of mercury inputs from Cornwall sources.

iv. Both north and south shore surficial sediments contained elevated levels of PCBs in 1979. Levels along the north shore exceeded the MOE guideline (50 ug/kg) for open water disposal at 61% of stations sampled; along the south shore, 64% of stations exceeded the guideline. Average sediment

concentrations were 221 ug/kg along the north shore and 348 ug/kg along the south shore. However, levels in some Massena area sediments were generally an order of magnitude higher than those from the Cornwall area, reflecting inputs from the Grasse River (ALCOA), Reynolds Metals and the General Motors Foundry.

Although no PCBs were detected in waters along the north shore, mean loadings of PCBs from Domtar (the major Ontario source) ranged from 16 g/d in 1980 to 58 g/d in 1979. The Cornwall sewage treatment plant (the second largest source) contributed loadings that ranged from 0.4 to 9 g/d to the river. Although loadings of PCBs from New York sources were not quantified during this study, PCBs were detected in some water samples from the Grasse River mouth and near the Reynolds Metals and General Motors outfalls in 1979. During 1980, 63% of samples from the Grasse River mouth contained PCBs exceeding the Provincial objective (0.001 ug/L) for the protection of aquatic life. Concentrations ranged from 0.020 to 0.070 ug/L. The calculated mean loading from the Grasse River during the 1980 surveys (62 g/d) was similar to the total from all Cornwall sources in 1979 (70 g/d) but much lower than the actual loading from the ALCOA plant to the Grasse River in 1980 (176 g/d to 281 g/d).

PCB levels in suspended solids reflected the high loading of PCBs from the Grasse River. A level of 0.66 ug/g in the suspended solids at the river mouth was the highest observed in the study area.

In addition, measurements of PCBs in the food chain in 1979 (macrophytes, benthic macroinvertebrates and spottail shiners) indicated that bioavailability was greatest along the New York shoreline. Spottail shiners, macroinvertebrates and macrophytes contained mean PCB levels of 2,072, 158 and 25 ng/g wet weight at the Grasse River mouth. Corresponding

maxima from the north shore were 243 ng/g, 50 ng/g and 5 ng/g, respectively. Subsequent sampling of spottail shiners suggested a significant decline in inputs to the Grasse River in 1981, although levels (1,117 ng/g) were still well above the Agreement objective of 100 ng/g. In contrast, 1979, 1980 and 1981 samples from Cornwall (range 234 to 367 ng/g) indicated no major change in PCBs loadings from Domtar.

While PCBs in sport fish from Lake St. Francis were within Health and Welfare Canada's unrestricted consumption guideline (2 mg/kg), levels exceeded the guideline in two commercial fish species (sturgeon and catfish).

v. In 1979, Domtar, which has the largest industrial discharge of wastewater in Cornwall, was the major point source of suspended solids, total dissolved solids, chloride, BOD_5, COD, nitrate and nitrite, fluoride, cyanide, aluminum, cadmium, chromium, copper, iron and lead. The Courtaulds/BCL acid and viscose sewers were the major sources of zinc. The major loadings of total phosphorus (TP) and total Kjeldahl nitrogen (TKN) came from Domtar and the Cornwall WPCP.

Effluent sampling also detected the presence of organochlorine pesticides (i.e. BHCs, chlordane, DDT and its metabolites, endrin, heptachlor epoxide and hexachlorobenzene) and chlorophenols (i.e. 2,4,6-trichlorophenol, pentachlorophenol) in Cornwall effluents, with Domtar, Courtaulds/BCL and the Cornwall WPCP being the major sources.

These findings were reflected in the downstream ambient river environment (below the Domtar discharge and in the vicinity of the Courtaulds/BCL complex) by exceedences of the objectives for phosphorus, copper, zinc, 2,4,6-trichlorophenol and pentachlorophenol in some water samples; by levels of TP, TKN, cadmium, chromium, copper, iron, lead, zinc and oils and greases which exceeded the Provincial dredging guideline in some surficial sediment samples; and by sediment concentrations of chlordane, DDE, beta-BHC and hexachlorobenzene above upstream background levels.

Further down river at Lancaster, exceedences of water quality objectives (p,p'-DDD, pentachlorophenol) and elevated concentrations of TP, TKN, dieldrin, chlordane, p,p'-DDE, PCBs and cadmium at the mouth of the Raisin River suggest sources in the watershed of this tributary.

vi. Important sources of nutrients and trace contaminants were also indicated along the New York shoreline, as indicated by objective exceedences or elevated levels in ambient river samples. For example, the objectives for TP, TKN, cadmium, copper, dieldrin, DDT and its metabolites and thiodan were exceeded in some water samples from the mouths of the Grasse, Raquette and St. Regis Rivers or the vicinity of the Reynolds Metals or General Motors Foundry outfalls. Exceedences of the 2,4,6-trichlorophenol and pentachlorophenol objectives and elevated levels of aluminum in some water samples from the Grasse River mouth and near the above outfalls also indicated sources.

Sediments taken near the mouths of the three tributaries also contained levels of TP, TKN, iron, zinc and oils and greases in excess of Provincial dredging guidelines, while the cadmium guideline was exceeded at the mouths of the Grasse and Raquette Rivers and copper and chromium at the Grasse River. Aluminum, dieldrin, chlordane, DDT and its metabolites, and beta and gamma-BHC were elevated at the mouth of the Grasse River and aluminum was also elevated near the Reynolds Metals and Geneal Motors discharges.

vii. The 1979 results also indicated that there are contributions of a number of contaminants from upstream sources. These included (and were detected in): mercury (water, suspended solids, spottail shiners); PCBs, BHCs, chlordane and DDT and its metabolites (bottom sediments); and oils and greases (suspended solids). The relative magnitude of this contribution as compared to Cornwall and Massena area inputs is not known at present.

viii. Preliminary full-scan GC/MS analyses of Cornwall effluents and selected suspended solids and bottom sediment samples identified a large number of organic compounds. However, quantification of loadings and hence, the major point sources of individual compounds could not be defined. Nevertheless, those that have been identified as priority pollutants (USEPA) or as chemicals requiring further evaluation (MOE), those which are hydrophobic or lipophilic, or those specific to certain industrial processes should be considered for future effluent and ambient studies to determine their major sources, loadings and environmental impacts.

SOMMAIRE

Des études menées en 1979, 1980 et 1982 ont permis d'éclaircir les questions importantes soulevées par les déversements industriels et municipaux de la région de Cornwall-Massena dans le Saint-Laurent. Les industries polluantes situées sur les rives ontariennes, comme Domtar Fine Papers, Cornwall Chemicals, Canadian Industries Ltd., Courtaulds et BCL ainsi que celles qui se trouvent dans l'État de New York, telles que ALCOA, Reynolds Metals Co. et la fonderie de General Motors, ont contribué à la détérioration de la qualité de l'eau et à la restriction de son utilisation dans la région de Cornwall-Massena.

Les grandes questions qui se dégagent de ces études sont les suivantes :

i. Les études menées en 1979 et 1980 ont permis de détecter dans les eaux de surface de Cornwall, près du rivage, des concentrations élevées de composés phénoliques non conformes aux objectifs provinciaux ni à ceux de l'Accord visant à éviter la contamination du poisson ainsi que les problèmes de goût et d'odeur de l'eau potable (1 ug/L). Lors de quelques enquêtes menées en 1980, cette zone de mélange s'étendait jusqu'à 8 km en aval du diffuseur commun à Domtar, CIL et Cornwall Chemicals. Ces conclusions correspondent assez bien avec les projections effectuées à l'aide d'un modèle à sources multiples et de données recueillies en 1979 sur les déversements de composés phénoliques. Les débits moyens de déversement de phénols de Domtar (235 kg/jour en 1979; 116 kg/jour en 1980) étaient sensiblement supérieurs à ceux des autres sources de polluants échantillonnées. Les différences entre les études menées sur ces déversements en 1980 ont été mises en relation avec la qualité de l'eau à l'origine. La dispersion des

polluants déversés par le diffuseur en place s'est révélée inadéquate en raison du fait que les points d'évacuation sont situés à proximité de la rive, en eau peu profonde.

Il est intéressant de noter que bien que la concentration de composés phénoliques dans les eaux ontariennes ne soit pas conforme aux objectifs, on n'a relevé aucune contamination du poisson ni aucun problème de goût ou d'odeur de l'eau potable pendant la durée de l'étude, ce qui laisse croire qu'une grande partie des composés phénoliques réactifs présents dans l'effluent de Domtar ne sont pas contaminants.

ii. Lors de certaines des études menées en 1980 et 1982, la densité de bactéries coliformes fécales (CF) dans les eaux de surface de Cornwall à proximité du rivage dépassait l'objectif provincial pour la protection des eaux à usages récréatifs (100/100 mL) jusqu'à 8 km en aval du diffuseur commun à Domtar, CIL et Cornwall Chemicals. Cette forte densité était imputable principalement à l'effluent de Domtar Fine Papers, étant donné que la fluctuation des concentrations dans le fleuve en 1980 correspondait bien aux fluctuations de la densité bactérienne et du débit de l'effluent de cette industrie. En outre, la densité de CF de l'effluent de Domtar dépassait généralement celle mesurée à d'autres sources (p. ex., CIL, exutoire de l'égout unitaire de l'av. Brookdale et usine d'épuration de Cornwall) et, en raison du débit élevé, il en résultait une charge importante en ce type d'organismes. Cependant, aucune donnée fiable n'a permis de déterminer si les CF déversés par Domtar étaient d'origine fécale (E. coli) ou plus naturelle (Klebsiella).

À quelques reprises, on a constaté que l'effluent de l'usine d'épuration de Cornwall contenait également une

forte densité de CF, ce qui reflétait une désinfection insuffisante des eaux usées. Cependant, ces déversements de l'usine avaient peu d'effets en aval.

Les fortes densités de CF observées à quelques reprises lors des études de 1980 et 1982 à proximité du complexe Courtaulds-BCL dénotaient un apport supplémentaire de bactéries dans le secteur, qui provenait peut-être de l'écoulement d'averse ou de déversoirs d'orage.

iii. En 1979, dans 65% des postes échantillonnés, la concentration de mercure dans les sédiments superficiels le long de la rive ontarienne du fleuve était non conforme à la ligne directrice du Ministère de l'Environnement relative au déversement direct de matières draguées (0,3 mg/kg). Les concentrations de mercure les plus élevées ont été mesurées dans des sédiments près des exutoires de Canadian Industries Ltd. (CIL) et de Courtaulds-BCL (un dépôt de sédiments, au moins temporaire, se produit à ce dernier emplacement). Immédiatement en aval de l'exutoire de CIL, les concentrations moyennes étaient semblables à celles de 1970 et de 1975; plus loin en aval (de 3 à 14 km), elles étaient plus basses. CIL, usine de chlor-alcali qui constitue une importante source de rejet de mercure, se conforme maintenant aux règlements s'appliquant aux usines de chlor-alcali (0,0025 kg de mercure par tonne de chlore par jour). Les pertes de mercure de CIL ont été réduites considérablement; elles sont passées de 590 kg/an en 1970 à 23 kg/an en 1979. La cause des autres déversements de mercure, comme ceux des égouts de Courtaulds-BCL, demeure inconnue.

Les données obtenues à partir d'échantillons d'eau filtrée de Cornwall indiquaient en 1979 que les concentrations de mercure étaient inférieures à

l'objectif provincial et à celui de l'Accord (0,2 ug/L). Néanmoins, des concentrations de mercure allant jusqu'à 2,4 mg/kg étaient fréquentes dans les matières solides en suspension près des sources, ce qui reflète les répercussions importantes des déversements de mercure sur le système aquatique.

Bien que du mercure ait été également détecté dans des échantillons prélevés en amont, les animaux benthiques, les queues à tache noire et les espèces de poisson recherchées par la pêche sportive étaient tous affectés par les déversements de mercure de Cornwall. Des concentrations allant jusqu'à 70 ng/g, ce qui est inférieur à l'objectif de l'Accord, soit 500 ng/g pour le poisson entier, ont été trouvées dans des queues à tache noire, alors que des concentrations moyennes de 0,2 et 0,3 ng/g ont été détectées dans des plantes aquatiques et des macro-invertébrés. Ces concentrations ont été mesurées à des postes où les concentrations de mercure dans les sédiments étaient également élevées. Les concentrations de mercure mesurées récemment dans les poissons de pêche sportive en aval du lac St. Francis ont subi une baisse significative par rapport à celles du début des années 70; cependant, la consommation de spécimens de grande taille (supérieure à 35 cm) de certaines espèces (le doré et le grand brochet) doit toujours être restreinte. Les données actuelles dénotent la nécessité de réduire encore plus ou d'éliminer les déversements de mercure par les sources de Cornwall.

iv. En 1979, les sédiments superficiels des rives nord et sud contenaient une concentration élevée de BPC. Les concentrations de cette substance étaient supérieures à la ligne directrice du Ministère (50 ug/kg) relative aux déversements directs dans 61 % des postes échantillonnés le long de la rive nord, et dans 64 % le long de la rive

sud. Les concentrations moyennes dans les sédiments étaient de 221 ug/kg le long de la rive nord et de 348 ug/kg le long de la rive sud. Cependant, les concentrations dans certains sédiments prélevés dans la région de Massena étaient en général jusqu'à dix fois supérieures à celles de la région de Cornwall en raison des déversements provenant de la rivière Grasse (ALCOA), de Reynolds Metals et de la fonderie de General Motors.

Bien qu'aucun BPC n'ait été détecté le long de la rive nord, les déversements moyens de BPC de Domtar (la principale source ontarienne de cette substance) se situaient entre 16 g/jour en 1980 et 58 g/jour en 1979. L'usine d'épuration de Cornwall (la deuxième source en importance) effectuait dans le fleuve des déversements variant de 0,4 à 9 g/jour. Bien que les déversements de BPC provenant de sources situées dans l'État de New York n'aient pas été quantifiés au cours de l'étude, des BPC ont été détectés en 1979 dans certains échantillons d'eau à l'embouchure de la rivière Grasse et près des exutoires de Reynolds Metals et de General Motors. En 1980, 63 % des échantillons prélevés à l'embouchure de la rivière Grasse contenaient une concentration de BPC variant entre 0,020 et 0,070 ug/L, soit supérieure à celle de l'objectif provincial (0,001 ug/L) pour la protection de la vie aquatique. La quantité moyenne de polluants provenant de la rivière Grasse mesurée pendant les études de 1980 (62 g/jour) se rapprochait du total des sources de Cornwall en 1979 (70 g/jour) mais était bien inférieure à la quantité réelle de polluants déversés dans la rivière en 1980 par l'usine ALCOA (de 176 g/jour à 281 g/jour).

La concentration de BPC dans les matières solides en suspension reflétait la quantité élevée de BPC provenant de la rivière Grasse. C'est dans les matières solides en

suspension à l'embouchure de la rivière qu'on a relevé la concentration de BPC la plus élevée de la zone d'étude, soit 0,66 ug/g.

En outre, les mesures de BPC dans la chaîne alimentaire effectuées en 1979 (macrophytes, macro-invertébrés benthiques et queues à tache noire) ont indiqué que la biodisponibilité était la plus grande le long de la rive située dans l'État de New York. Les queues à tache noire, les macro-invertébrés et les macrophytes contenaient des concentrations moyennes respectives de BPC de 2 072, 158 et 25 ng/g (humide) à l'embouchure de la rivière Grasse. Les maximums correspondants pour la rive nord étaient de 243, 50 et 5 ng/g respectivement. Un échantillonnage ultérieur de queues à tache noire laissait croire à une baisse importante de la pollution de la rivière Grasse en 1981, mais la concentration relevée (1 117 ng/g) était toujours bien supérieure à celle de l'objectif de l'Accord, à savoir 100 ng/g. Par contre, des échantillons prélevés en 1979, 1980 et 1981 à Cornwall (concentration de 234 à 367 ng/g) ne dénotaient pas de changement important dans les déversements de BPC effectués par Domtar.

Alors que la concentration de BPC dans les poissons de pêche sportive du lac St. Francis était inférieure à la norme de consommation libre fixée par Santé et Bien-Être social Canada (2 mg/kg), elle la dépassait dans le cas de deux espèces de poisson pêchées à des fins commerciales (l'esturgeon et le poisson-chat).

v. En 1979, la société Domtar, dont le volume de l'effluent industriel est le plus important de Cornwall, constituait la source ponctuelle principale de matières solides en suspension, de matières solides totales en solution, de chlorure, de DBO_5, de DCO, de nitrate, de nitrite, de

fluorure, de cyanure, d'aluminium, de cadmium, de chrome, de cuivre, de fer et de plomb. Les déversements d'acide et de viscose de Courtaulds-BCL constituaient les principales sources de zinc. La plus grande partie du phosphore total (PT) et de l'azote total Kjeldahl (NTK) venait de Domtar et de l'usine d'épuration de Cornwall.

Des échantillons d'effluents prélevés à Cornwall ont également révélé la présence de pesticides organochlorés (hexachlorobenzène, chlordane, DDT et ses métabolites, endrine, époxyde d'heptachlore et chlorophénols (2,4,6-trichlorophénol, pentachlorophénol). Domtar, Courtaulds-BCL et l'usine d'épuration de Cornwall en sont les principales sources.

Ces conclusions se sont reflétées sur l'état du fleuve en aval (sous l'exutoire de Domtar et dans les environs du complexe Courtaulds-BCL) : non-conformité aux objectifs pour le phosphore, le cuivre, le zinc, le 2,4,6-trichlorophénol et le pentachlorophénol dans certains échantillons d'eau; concentrations de PT, de NTK, de cadmium, de chrome, de cuivre, de fer, de plomb, de zinc, d'huiles et de graisses non conformes à la ligne directrice provinciale en matière de dragage dans certains échantillons de sédiments superficiels; concentrations de chlordane, de DDE, de bétahexachlorobenzène et d'hexachlorobenzène dans les sédiments supérieures aux concentrations de fond notées en amont.

En aval, étant donné qu'à Lancanster les objectifs de qualité de l'eau ne sont pas respectés (p,p'-DDD, pentachlorophénol) et qu'à l'embouchure de la rivière Raisin les concentrations de PT, de NTK, de dieldrine, de chlordane, de p,p'-DDE, de BPC et de cadmium sont élevées, il semble y avoir des sources de pollution dans le bassin versant de cet affluent.

vi. Des sources importantes de substances nutritives et de polluants à l'état de traces ont été découvertes le long de la rive du fleuve dans l'État de New York, comme l'indique le dépassement des objectifs ou les concentrations élevées de polluants dans les échantillons prélevés. Par exemple, les objectifs relatifs au PT, au NTK, au cadmium, au cuivre, à la dieldrine, au DDT et à ses métabolites et au thiodan ont été dépassés dans certains échantillons d'eau provenant de l'embouchure des rivières Grasse, Raquette et St. Regis et à proximité de Reynolds Metals ou des exutoires de la fonderie de General Motors. Le dépassement des objectifs relatifs au 2,4,6-trichlorophénol et au pentachlorophénol ainsi que les concentrations élevées d'aluminium dans certains échantillons d'eau provenant de l'embouchure de la rivière Grasse et près des exutoires mentionnés ci-dessus laissaient également croire à l'existence de sources de pollution.

Des sédiments prélevés près de l'embouchure des trois affluents contenaient également des concentrations de PT, de NTK, de fer, de zinc, d'huiles et de graisses qui dépassaient les lignes directrices provinciales en matière de dragage; en outre, la ligne directrice du cadmium était dépassée à l'embouchure des rivières Grasse et Raquette et celles relatives au cuivre et au chrome l'étaient à la rivière Grasse. Les concentrations d'aluminium, de dieldrine, de chlordane, de DDT et de ses métabolites ainsi que de bêtahexachlorobenzène et de gammahexachlorobenzène étaient élevées à l'embouchure de la rivière Grasse, et l'aluminium se trouvait également en forte concentration près des exutoires de Reynolds Metals et de General Motors.

vii. Les résultats de 1979 ont également permis de constater que des sources situées en amont déversent de nombreux polluants. En voici la liste, avec, entre parenthèses, le milieu où ils ont été détectés : mercure (eau, matières solides en suspension, queues à tache noire); BPC, hexachlorobenzène, chlordane et DDT et ses métabolites (sédiments de fond); huiles et graisses (matières solides en suspension). L'ampleur relative de ces déversements par rapport à ceux de la région de Cornwall et de Massena demeure inconnue pour le moment.

viii. Des analyses préliminaires et complètes par chromatographie en phase gazeuse et spectrométrie de masse des effluents de Cornwall, d'échantillons de matières solides en suspension et de sédiments de fond ont permis de révéler un grand nombre de composés organiques. Cependant, il n'a pas été possible de déterminer le volume des déversements et, par conséquent, les principales sources ponctuelles de ces composés. Néanmoins, à l'égard de ceux qui ont été désignés polluants prioritaires (USEPA) ou produits chimiques devant être soumis à d'autres évaluations (ministère de l'Environnement), ceux qui sont hydrophobes ou lipophiles, ou ceux qui sont produits par certaines activités industrielles particulières, on devrait envisager des études ultérieures sur les effluents et le milieu ambiant afin d'en déterminer les sources principales, la quantité déversée et les répercussions sur l'environnement.

RECOMMENDATIONS*

Based on the 1979, 1980 and 1982 study results, it is recommended that:

1. Additional analysis of Domtar effluent be conducted to identify and quantify the various phenol species present. Based on the results, this may also require a re-evaluation or re-definition of the present 1 ug/L phenolics objective, particularly as it pertains to pulp and paper mill discharges.

2. Modifications be made to the Domtar/CIL/Cornwall Chemicals combined diffuser outfall to improve mixing and minimize downstream impacts of this major Cornwall point source.

3. Sampling of Domtar process streams be conducted to determine the source(s) of, and aid in the reduction of, high fecal coliform densities in the final effluent. This requires the development of analytical methodologies specific for E. coli and Klebsiella and may also result in a re-evaluation or re-definition of the Provincial fecal coliform objective of 100 organisms/100 mL, as it pertains to the impact of pulp and paper mill discharges.

4. Additional fecal coliform sources (possibly storm runoff or combined sewer overflows) indicated in the Courtaulds/BCL area of the Cornwall waterfront should be identified and eliminated.

5. Sources of PCBs detected in the final effluents of most Cornwall point sources (in particular the major contributor, Domtar) and in Massena at the mouths of the Grasse, Raquette and St. Regis Rivers and near the Reynolds Metals and General Motors outfalls should be identified, minimized and if possible eliminated. This is necessary to reduce PCB concentrations in sport fish and local forage fish.

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* Subsequent studies or actions which address these recommendations are summarized in the Foreword of this report.

6. Although the CIL chlor-alkali plant's mercury discharge complied with Federal requirements, consideration should be given to further loading reductions or elimination of mercury discharge entirely. This, as well as the identification and elimination of sources from other Cornwall point sources (e.g. Courtaulds/BCL) should result in further substantial reductions in sport fish.

7. Follow-up studies should be initiated to determine the sources, loadings and impacts of those priority pollutants and contaminants requiring further evaluation which were identified in selected 1979 effluent and river sediment samples.

8. The MOE, in conjunction with industry, should develop or adapt technologies to minimize or eliminate the discharge of hazardous and/or persistent contaminants (metals, pesticides, PCBs, phenols, chlorophenols, etc.) identified in Cornwall effluents. Furthermore, regulations for the control, monitoring and compliance of these discharges need to be developed and implemented by the Ministry.

9. A study should be conducted to determine the effect of contaminants inputs on benthic macroinvertebrate numbers and species and, by comparison with previous (1966) data, determine the effectiveness of subsequent remedial measures initiated by Cornwall dischargers.

1. INTRODUCTION

This report deals with the impact of municipal and industrial discharges on water quality in the Cornwall, Ontario and Massena, New York reach of the St. Lawrence River during the years 1979, 1980 and 1982 (see Figure 1 for study area location)

1.1 Description of the Study Area

Since the opening of the Seaway in 1959, the St. Lawrence river has become an important transportation corridor for both Canada and the United States.

The following sections provide a brief description of the physical, chemical and water use characteristics of the St. Lawrence River, with special emphasis on the Cornwall and Massena areas.

1.1.1 Watershed and Discharge Rate

The St. Lawrence River is the final outlet of the Laurentian Great Lakes, which have a drainage basin of 774,000 km^2. About 86% of the flow entering the St. Lawrence River from Lake Ontario is from the other four Great Lakes, and inputs from the river's wastershed have relatively little effect on flow or water level. For the 95 years prior to the St. Lawrence Seaway development, the mean annual discharge recorded at Iroquois, Ontario was 6,819 cms* (Owen and Veal, 1968). During the post-Seaway development period from 1975 to 1982, the mean annual discharge recorded at Cornwall, Ontario was 7,183 cms (U.S. Dept. of Commerce, National Oceanographic and Atmospheric Administration - National Ocean Survey, Rockville, Maryland). This higher discharge rate is largely attributable to high flows during the 1970's resulting from regulation of the Lake Ontario water level at the Iroquois Control Dam. Other, less significant, controlling structures are the Long Sault Spillway Dam, the Wiley-Dondero Canal, the Cornwall Canal Dam, and the Massena Canal (see Figure 2).

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* 1 cms (cubic metre/second) = 35.7 cfs (cubic feet/second)

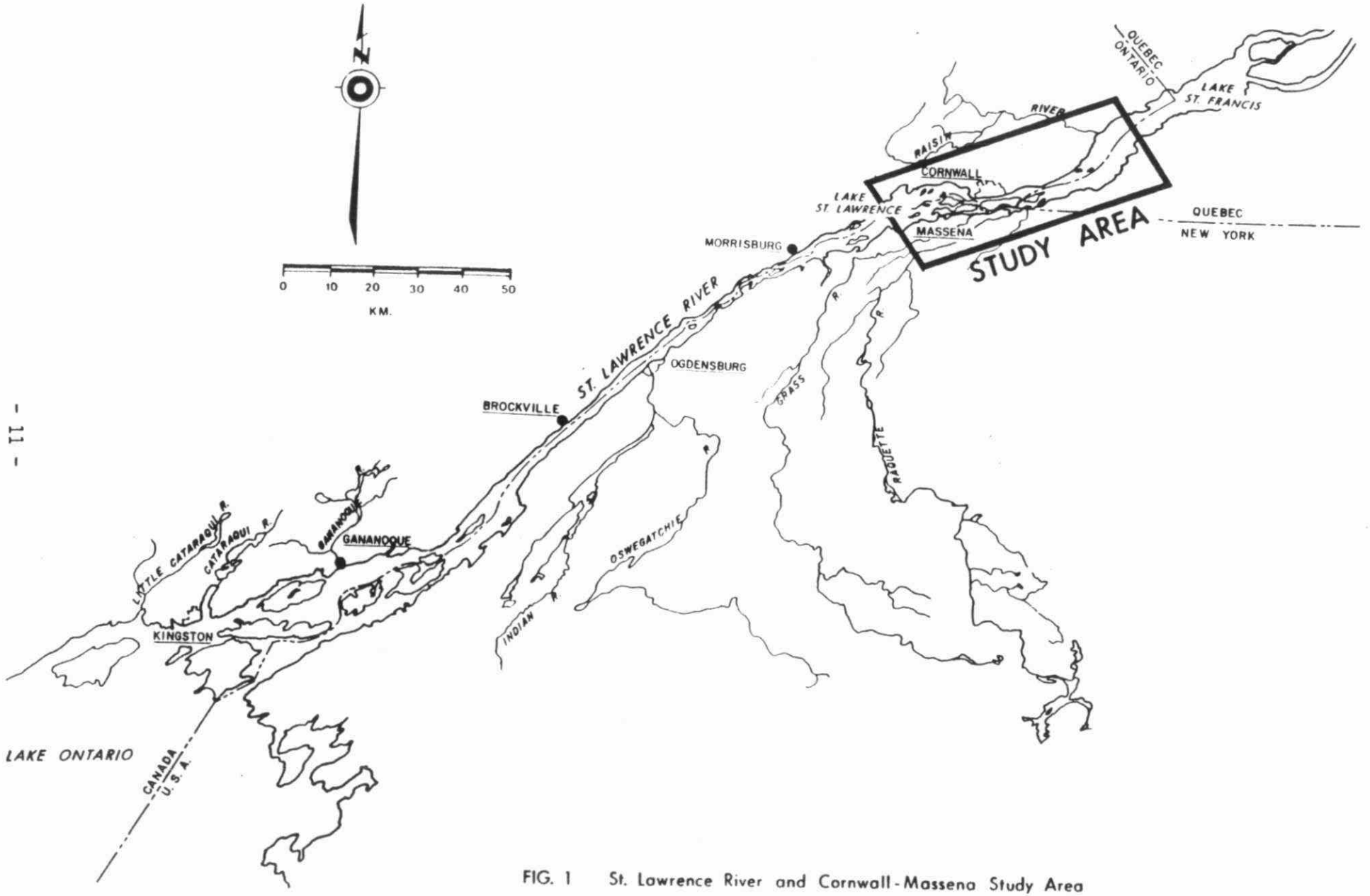

FIG. 1 St. Lawrence River and Cornwall-Massena Study Area

The major tributaries entering the St. Lawrence River in the Cornwall-Massena area are all located on the south (New York State) side. Their watershed area, average annual discharge and population are as follows (IJC, 1985):

	Watershed (km^2)	Discharge (cms)	Population
Grasse River	1667	31.9	36,060
Raquette River	3257	59.7	32,800
St. Regis River	2357	29.8	-

Massena, New York (in the Grasse River watershed) and Cornwall, Ontario are the major communities and industrial centres on the international section of the St. Lawrence River, with populations of about 15,000 and 46,000, respectively.

1.1.2 Physical Characteristics and Geology

In the Cornwall area, the bedrock is typically Ordovician limestone or shale, overlain by dark grey gleisolic soil. Tributaries entering the river in the Massena area drain regions of Cambrian sandstone overlain by brown podzol soils.

The Long Sault Spillway Dam combines with the Moses-Saunders Power Dam at Cornwall to regulate the level of Lake St. Lawrence. The formation of this lake (average depth: 8 m) upon completion of the seaway vastly altered morphometric and hydrological features of the river as far upstream as Iroquois (Owen and Wile, 1975). East of the Moses-Saunders Dam, the river divides into a north (Cornwall) and south (international) channel around Cornwall Island. These channels carry approximately one third and two thirds, respectively, of the total discharge of the river. Current speeds can reach 3 to 6 knots (1.5 to 3.0 m/sec).

Downstream of Cornwall, the river widens abruptly into the long shallow reach of Lake St. Francis (Lac St. Francois) where the current slows to less than 2 knots. Mean depth is 5.5 m, although much of this lake is less than 3m deep. Although the water level of Lake St. Francis is affected by the Moses-Saunders and Long Sault dams, the principal regulators are the control and Hydro Quebec power dams located at Beauharnois, Quebec (Owen and Wile, 1975). Consequently, lake water level fluctuation is minimal.

1.1.3 Historical Water Quality Issues

Although water quality of the mainstream St. Lawrence waters generally reflects that of the major source (Lake Ontario), local inputs (both point source and tributary) have the potential to affect local, nearshore water quality.

As early as 1913, monitoring data indicated that the St. Lawrence River from the Thousand Islands region to Cornwall was bacterially contaminated. This problem was ascribed to the discharge of sewage from vessels and by communities along the river (IJC, 1914).

More recent water quality information dates from the years subsequent to the development of the St. Lawrence Seaway. In the Cornwall - Massena - Lake St. Francis reach of the river, Ontario Water Resources Commission surveys were conducted to assess the status of municipal pollution control programs (OWRC, 1964) as well as river water quality (OWRC, 1965). Water quality monitoring by the Federal Department of Health and Welfare from 1965 to 1967 indicated localized inputs of phenols, coliform bacteria and phosphorus in the Cornwall area; organic nitrogen (nitrite) in the Massena (Grasse River) area; and coliform bacteria in the Grasse River and St. Regis River areas (IJC, 1969). Elevated levels of phenols and coliform bacteria (total and fecal) were also detected along the north shore of the river in the Cornwall area during 1972 Ontario Ministry of the Environment studies (MOE, 1972). A 1975 study undertaken to assess the effects of major Cornwall municipal and industrial dischargers found high fecal coliform densities in St. Lawrence River surface waters downstream of the Courtaulds/BCL outfalls (Experience '75). However, the source or sources of contamination were not identified at that time. Elevated total and fecal coliform densities were also found in this area of the river during some surveys conducted by Environment Canada in 1977 (CCIW, 1978). During these same surveys, high levels of phosphorus, aluminum and zinc were detected at the mouths of some of the tributaries (e.g. Grasse River) discharging to the southern shore of the river. High levels of zinc were also observed in the Cornwall area (Chan, 1980).

Impacts of pollution on resident organisms has also been noted. Benthic community studies by the OWRC in 1966 revealed that nearshore waters along most of the Cornwall waterfront were grossly impaired. Bottom sediments were blanketed with bark and wood chips and benthic macroinvertebrates were absent for as far as 5 km downstream of the Howard Smith paper mill (now owned by Domtar Fine Papers Ltd.). Although impairment of the benthic community was not observed in downstream Lake St. Francis, excessive aquatic macrophyte production was noted throughout the upper portion of the lake (Owen and Veal, 1968). Indeed, major changes in plant species dominance as well as associated communities of invertebrates and fish species have occurred along the northern shore of Lake St. Francis since the construction of the St. Lawrence Seaway. These are largely ascribed to the accumulation of finer, predominantly organic sediments in extensive areas of shallow water (Owen and Wile, 1975).

While problems resulting from inputs of conventional contaminants such as nutrients and bacteria have been apparent in this section of the river for many years, the presence of more persistent contaminants, particularly in the sediments and indigenous biota, have recently become a concern. For example, levels of polychlorinated biphenyls (PCBs) and mercury in larger sizes of some sport and commercial fish from the Cornwall and Lake St. Francis areas have been above the guidelines for human consumption set by the Canada Department of National Health and Welfare, necessitating restricted consumption advisories for these species (MOE/MNR, 1978-82). Moreover, commercial fishing for carp, white sucker and eels in this area has been closed sporadically in the late 1970's and early 1980's due to PCBs or mercury contamination. A recent review by Couillard (1982) concluded that PCB and organochlorine concentrations in fish and sediments from the Cornwall to Quebec City section of the river were highest in Lake St. Francis and decline downstream.

Elevated mercury levels were also found in north shore river sediments for at least 20 km downstream of Cornwall in 1970. By 1975, this zone of elevated levels had decreased in longitudinal extent to 11-14 km (MOE, 1977). A similar decline was also evident in sport fish (MOE, unpublished data) and is attributed to the 1970 reduction in mercury loadings from the CIL chlor-alkali plant and the termination of mercurial slimicide use at the Domtar Fine Papers mill (OWRC, 1970; MOE, 1977).

In 1977, surveys by Environment Canada detected PCBs in some water samples from the Grasse River mouth (Chan, 1980). This led to the Grasse River's designation as a problem area (where Great Lakes Water Quality Agreement objectives were exceeded or where desired water uses could not be achieved) in 1978 (IJC, 1978a). New York state data for some sports fish (Armstrong and Sloan, 1980) also indicated a continuing input of PCBs to this river.

1.1.4 Water Uses

The Cornwall-Massena area of the St. Lawrence River supports a wide variety of industrial and recreational water uses. These include commercial and recreational navigation, hydro-electric power generation, domestic and industrial water supplies, waste assimilation, fishing, swimming and camping.

The water treatment plant (WTP) of the City of Cornwall draws about 22 MIGD from Lake St. Lawrence above the Moses-Saunders power dam (Figure 2). The water intake for the Glen Walter Nursing Home (which closed down in 1985 and is now owned and operated as a private school by the Al-Rasheed Islamic Institute) is located 190 m from shore about 0.5 km downstream of Pilon Island and withdraws about 1.3 MIGD (Figure 2) . Private dwellings in the Cornwall area not serviced by the municipal water supply employ ground water. Also, summer cottages and homes occupy much of the downstream shore and many of these residences obtain their water from the river.

The Village of Massena WTP intake located at the inlet to the Massena Canal, also draws water from Lake St. Lawrence (Figure 2).

The Cornwall-Massena section of the St. Lawrence River provides important spawning and nursery habitat for a number of fish species (Goodyear et al., 1982) and Lake St. Lawrence and Lake St. Francis are very heavily fished by sport anglers. Yellow perch, yellow pickerel (walleye), smallmouth bass, northern pike and muskellunge are the principal species caught. In addition, three commercial fishermen are licenced to take fish (brown bullhead, sunfish, carp, white sucker and American eel) and the Cornwall St. Regis Akwesasne Indian Band utilize fish (yellow perch, walleye and sturgeon) from this reach of the river as a food source (IJC, 1985).

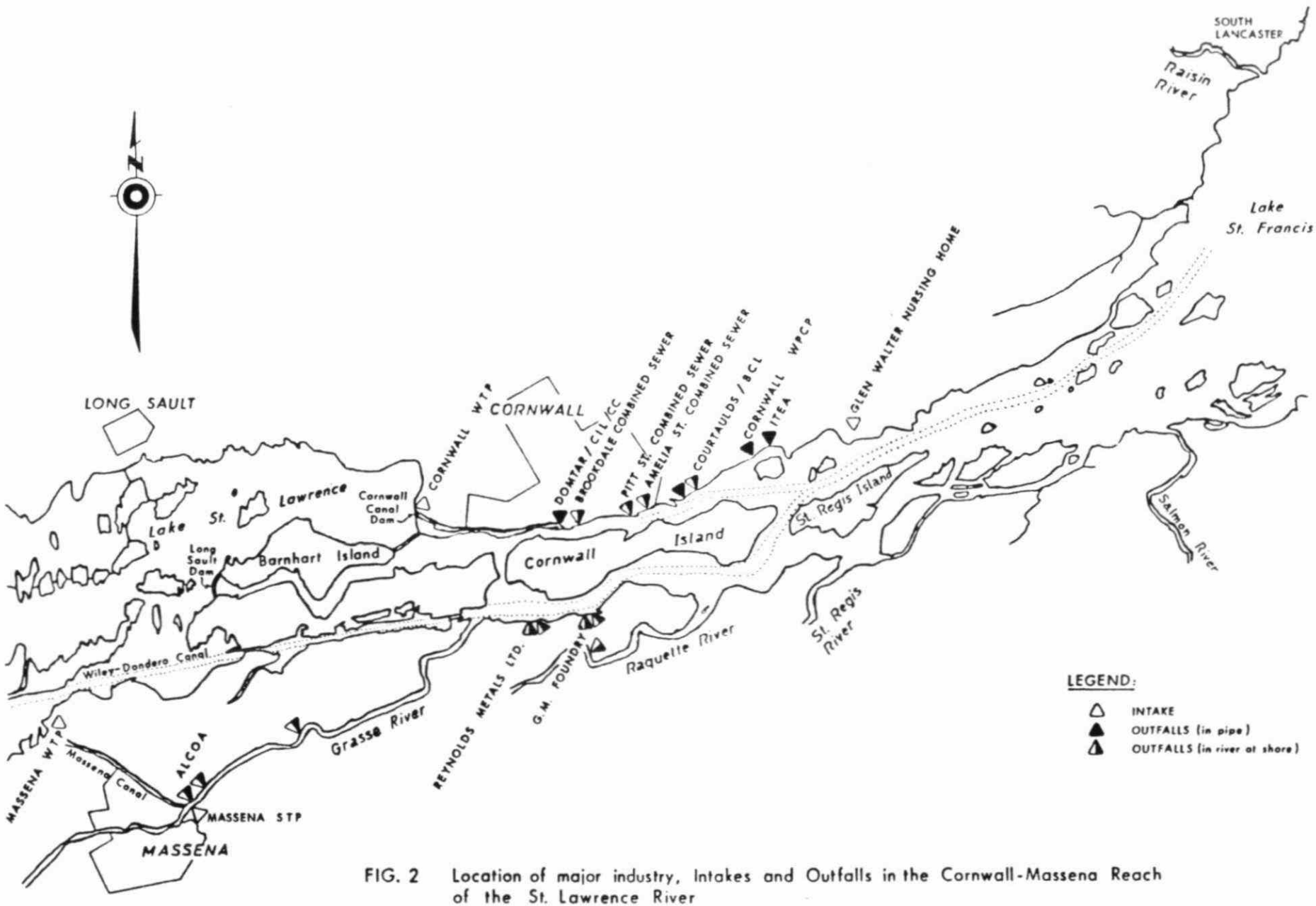

FIG. 2 Location of major industry, Intakes and Outfalls in the Cornwall-Massena Reach of the St. Lawrence River

Downstream of Cornwall and as far as the Quebec border, the river is important for both recreation and fishing. There are four public beaches between Cornwall and the Quebec border. However, due to elevated fecal coliform counts, the beaches in the area have occasionally been closed in recent years.

1.2 Objectives of the Present Study

The 1979, 1980 and 1982 investigations described in this report were designed to:

(i) Provide an update of the status of water and sediment quality with regard to both conventional and persistent contaminants.

(ii) Determine the major point sources of contaminants.

(iii) Identify the impact of industrial and municipal discharges on water, sediments and biota with respect to both the Canada-U.S. Agreement and Provincial Water Quality Objectives.

(iv) Determine cause-effect relationships and recommend remedial measures.

2. MATERIALS AND METHODS

2.1 Field Sampling

Field methods, particularly with regard to sample handling and preservation, were as described in "A Guide to the Collection and Submission of Samples for Laboratory Analysis" (MOE, 1979).

In 1979, water quality investigations in the Cornwall-Massena area extended from September 21 to October 10 and included the monitoring and analysis of metals, organochlorine pesticides, PCBs, phenolics and nutrients. River water samples were collected at mid-depth using a teflon-lined Nansen bottle or a Kemmerer bottle at the stations indicated in Figure 3. Multiple (3-8) samples were taken at most stations; however, only one sample was obtained at stations 060 and 057. In addition, daily composite samples were obtained at Cornwall, Ontario intakes (raw water) and outfalls (final effluent); locations of these, as well as the major New York discharges (which were not sampled) are shown in Figure 2. A limited number of effluent samples were also analyzed by GC/MS scan to identify other organics of potential importance for future studies.

During the 1979 study, sampling was also conducted to determine concentrations of nutrients, metals, organochlorine pesticides, PCBs and oils and greases in bottom sediments and to provide insight into materials that have or are being discharged to the St. Lawrence River in the Cornwall, Ontario and Massena, New York areas. The 64 sampling locations are shown in Figure 3. These were mainly located in the nearshore of the river, away from the dredged shipping channel and at or downstream of potential sources (point or tributary). At each station, the surficial (0-3 cm) layer of sediment from 3 or more Shipek grabs was composited and submitted for the above analyses as well as for particle size distribution and carbon content.

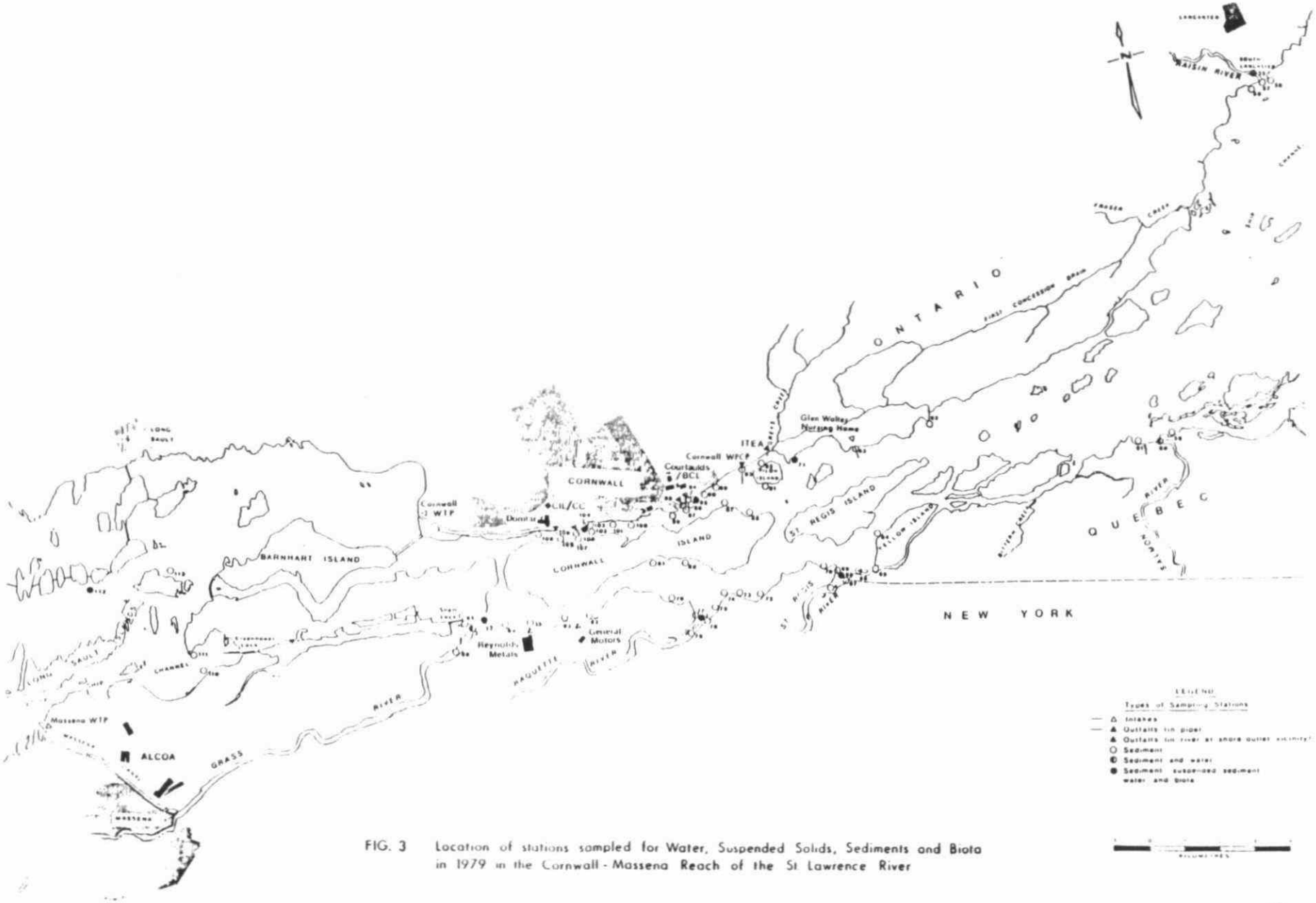

FIG. 3 Location of stations sampled for Water, Suspended Solids, Sediments and Biota in 1979 in the Cornwall - Massena Reach of the St Lawrence River

The distribution of contaminants between water, sediment and biota was also studied at selected locations in 1979. Water and sediment samples were collected (once) at stations 112, 104, 095, 033, 003, 068, 071 and 055 as outlined above. At the same time, suspended sediments were collected (at mid-depth) over a 3 hour period by continuous-flow centrifuge (Alfa Laval, Model 103B) and macrozoobenthos and macrophytes were collected for identification and chemical analysis. Sufficient biomass of benthic macroinvertebrates was obtained by sieving and hand-picking 6 to 10 Ponar grabs at each site. Macrophytes (exclusive of roots) were collected using a rake dragged along the bottom. Samples were submitted for metals, organochlorine pesticides, PCBs and chlorinated phenols/phenoxy herbicides analysis. GC/MS scans were performed on water and bottom sediment samples only. In addition, young-of-the-year spottail shiners (Notropis hudsonius), an important forage fish species, were collected by K. Suns of the Water Resources Branch in the fall of 1979, 1980 and 1981, using a 20 m bagseine (0.6 cm mesh). Locations of these sites are noted in Figure 3.

A further detailed study, aimed at defining the distribution of phenolics and bacteria along the Ontario side of the river was undertaken in 1980. Water samples were collected at a depth of 1.5 m at 18 river stations (Figure 4) and from selected Cornwall dischargers during five surveys (June 24-26; July 29-31, Sept 9-11; Oct. 21-23; Nov. 25-27). These effluent samples, as well as water samples from the mouth of the Grasse River, were also analyzed for organochlorine pesticides and PCBs.

Sampling for bacteria was repeated in 1982 to define the lateral and longitudinal extent of the problem. Samples were collected from 33 river stations (many of which were sampled in 1980 - see Figure 4) and selected Cornwall dischargers during two surveys (Aug. 6-9; Sept. 28-30).

Bacterial samples were analyzed for fecal coliforms, fecal Streptococcus and Pseudomonas aeruginosa. They were also analyzed for Escherichia coli and Klebsiella; however recent information has revealed that the testing procedures employed in 1982 were unreliable, and therefore the data will not be discussed in this report.

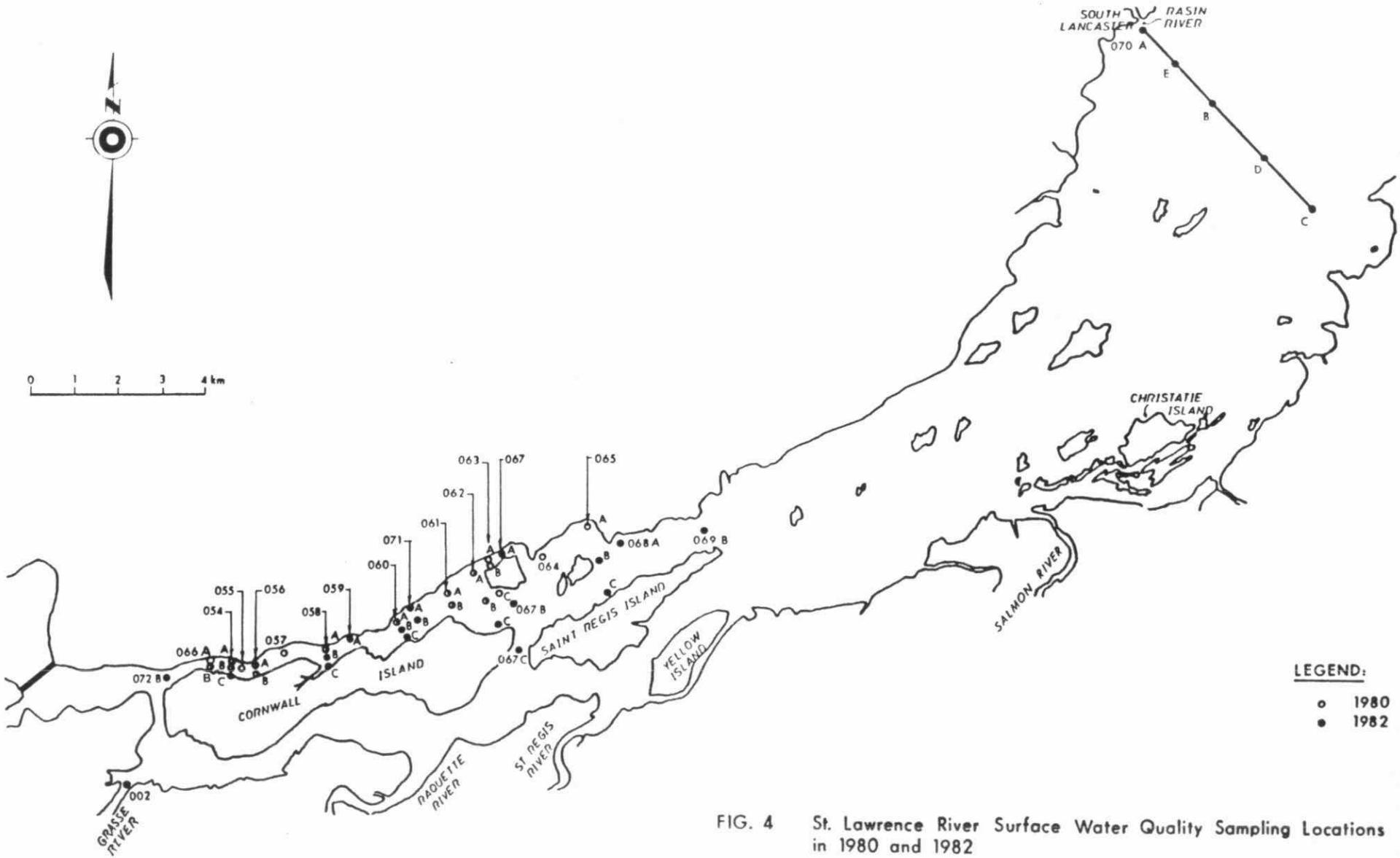

FIG. 4 St. Lawrence River Surface Water Quality Sampling Locations in 1980 and 1982

2.2 Laboratory Analyses

Chemical analyses were performed by the Ontario Ministry of the Environment laboratories in Rexdale, Ontario. Bacteriological analyses were carried out by the Ministry of the Environment's Southeastern Region laboratory in Kingston, Ontario. Detailed analytical methods are described in the "Handbook of Analytical Methods for Environmental Samples" (MOE, 1980).

3. POINT-SOURCE DISCHARGES AND STATUS OF REMEDIAL MEASURES

This section describes municipal and industrial discharges in the Cornwall and Massena areas (see Figure 2 for locations) and provides a historical perspective on remedial measures. Although not gathered as part of this study, information on effluent toxicities of the Cornwall discharges is also included.

3.1 Ontario

Three Cornwall industrial complexes discharge significant quantities of wastewater to the St. Lawrence River. These are: Canadian Industries Ltd. (CIL), Domtar Fine Papers and the Courtaulds (Canada) Ltd./British Cellophane Ltd. (BCL) facilities.

CIL operates a chlor-alkali plant to produce chlorine and sodium hydroxide from salt using the mercury cell process. On the same site, Cornwall Chemicals, partially owned by CIL, produces carbon tetrachloride, carbon disulphide, sodium hydrosulphide, chlorinated paraffins and hydrochloric acid. The chlor-alkali plant came into operation in 1935 and has discharged treated effluent containing mercury since then. CIL has been in compliance with federal regulations for mercury discharges since the early seventies. Provincial BOD_5* and suspended solids requirements have also been met during the same period.

Domtar Fine Papers Ltd. owns a large pulp plant and specialty paper mill at Cornwall. This mill converts purchased pulp and pulp produced from hardwood logs and chips by the Kraft pulping process (400 tons/day) into commodity paper (650 tons/day). In 1972, the sulphite pulp mill was shut down and a dry debarking and clarifier operation was installed to reduce the BOD_5 and suspended solids loadings. In 1974 and 1975, Domtar began using a steam stripper and Copeland reactor, respectively. These measures helped to reduce the high BOD_5 load to the St. Lawrence River from this plant. In 1982, a Control Order was issued to Domtar to further reduce excessive levels of suspended solids in its effluent. Domtar's effluent (30 MIGD) combines with the CIL (0.5 MIGD) and Cornwall Chemicals (0.2 MIGD) effluents prior to their collective discharge through a common multi-port diffuser outfall extending 76 m into the river.

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* 5-day biological oxygen demand
MGD = million gallons/day
1 MGD (U.S.) = 0.8 MIGD (Imp.)
1 MIGD = 2.20×10^{-4} m^3/day

Courtaulds (Canada) Ltd. and its associated company, British Cellophane Ltd. (BCL)* operate adjacent factories. Courtaulds manufactures rayon fiber from wood pulp and provides viscose to BCL, from which cellophane film is produced. The two companies discharge effluent through common sewers to the St. Lawrence River. BCL effluent comprises the majority of the discharge from the sulphide sewer (0.4 MIGD) while the viscose sewer (1.6 MIGD) is used mainly by Courtaulds. Courtaulds and BCL contribute about equally to the effluent of the acid sewer (1.6 MIGD) and a storm sewer. These effluents were the most toxic of the Cornwall industries tested (Table 1) and among the most toxic of those from all of Ontario (MOE, 1982 c). In 1977, a Control Order was issued to Courtaulds requiring a reduction in sulphuric acid, zinc, BOD_5 and suspended solids loadings, plus installation of an extended diffuser outfall. The acid and sulphide sewer discharges now reach the river via diffuser-equipped outfalls extending 240 m and 260 m, respectively, from shore. However, sulphuric acid and BOD_5 loadings are still considerably above Provincial objectives. Modernization of the plant reduced the loadings considerably but not enough to reach desirable levels. A new Control Order is currently under negotiation to reduce these levels even further. It is expected to be issued in early 1987.

BCL was also issued a Control Order in 1977 to meet Provincial requirements for BOD_5, suspended solids and sulphuric acid, as well as the installation of an extended diffuser outfall. The last requirement of the Control Order had to be met by 1982; however, the company has a legal obligation to continue to comply with the levels specified in the order.

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* Prior to September, 1980, the company name was Transparent Cellulose Film of Canada Ltd. (T.C.F.)

The Cornwall Water Pollution Control Plant (WPCP) is a primary facility equipped with phosphorus removal. In addition to municipal waste, it also receives inputs from several local industries. The average daily flows for 1981 and 1982 were 10.66 MIGD and 10.44 MIGD, respectively. Poor removal efficiences for BOD_5 and phosphorus were experienced at this plant in the past and continued to be a problem until mid-1982, even after phosphorus removal become operational in 1979. This was due to industrial waste interference with the chemical precipitation process. However, improvement in the quality of contributing industrial discharges over the last few years has resulted in good suspended solids, BOD_5 and phosphorus removal at the facility. The Cornwall WPCP discharges via a 607m - long diffuser - equipped, submerged, outfall located south-west of Pilon Island on which a number of summer cottages are located. However, the summer inhabitants of the island use the St. Lawrence River as a source of non-drinking water, while wells or bottled water from the mainland supply drinking water.

Since the older areas of Cornwall mainly have combined sewers, bypasses from the sewer system directly to the river can occur during spring runoff and storm events. It was previously recommended (Gore and Storrie, 1980) that the wet weather flow design capacity of the Cornwall WPCP be extended from 12 MIGD to 36 MIGD. However, upon reconsideration by the City of Cornwall, this was reduced to a maximum wet flow rate of 24 MIGD. This new proposed design capacity was possible with the use of the River Front Intercepting sewer as "storage" for storm event overflows. In order to implement this sewer as a "storage" area the sewer would have to be surcharged during overflow events. To avoid surcharging the eastern trunk sanitary sewer, since they share a common inlet chamber, a control gate would have to be installed upstream from the pumping station. This would in effect isolate the sanitary and intercepting sewers.

ITEA Textiles produced dyed drapery fabric. Wastes from the dying process were discharged directly into the river through a submerged outfall near Grays Creek. This facility, while operative during the 1979 survey, was subsequently taken over by Euro Curtains in late 1979, who continued to run the same operation. In 1982 Marimac Inc. purchased the company and established a similar operation which produces polyester sheer drapery fabric. It discharges wash water wastes into the river via a submerged outfall.

TABLE 1

TOXICITY OF CORNWALL EFFLUENTS

EFFLUENT	96-HOUR LC 50 (v/v)*
Domtar	59-94%
CIL	71%-NL
Cornwall Chemicals	71-87%
Courtaulds/BCL acid	0.1-4%
Courtaulds/BCL sulphide	2%-NL
Courtaulds/BCL viscose	2-14%
Cornwall WPCP	NL
ITEA	10-50%

Source: MOE, 1982c.

* volume/volume dilution of effluent, in percent, which will kill 50 percent of the test animals (Salmo gairdneri) in 96 hours at 15° C (e.g. 96-hour LC 50 = 10% = 10% effluent/90% dilution water). Range of values is for 1979 to 1981, inclusive.

NL = not lethal at 100%

3.2 New York State

Massena has a major concentration of aluminum producers and associated industries.

The Aluminum Company of America (ALCOA) facility is an integrated aluminum plant including reduction, casting and manufacture of ingot, wire rod and bar products. The company's wastewater treatment system currently consists of a series of lagoons for waste stabilization (including a sanitary waste lagoon) for treating the total plant wastewaters. All major non-sanitary waste flows are now directed to the secondary lagoon for treatment prior to discharge (18 MGD* average) into the Grasse River at a point approximately 10 km upstream of the river mouth. The company is attempting to identify and eliminate a small number of continuing sources of PCBs to the plant's waste stream. The New York State Dept. of Environmental Conservation (NYSDEC) has proposed a total PCBs limit of 1 ppb daily average and 2 ppb daily maximum for the wastewater discharge permit when it is renewed in 1984 (IJC, 1982).

The General Motors Central Foundry primarily manufactures cast aluminum automotive products. A PCB-based hydraulic fluid was utilized in some die casting machines until 1973. Intake water for this plant is drawn from the St. Lawrence River downstream of the confluence with the Grasse River and has been found to contain detectable levels of PCBs.

A closed-loop system is employed at this foundry for process and effluent water, with intermittant discharge of about 0.25 MGD to the St. Lawrence River via two outfalls. A further 0.19 MGD reaches the Raquette River from a storm water collection lagoon. General Motors has initiated an extensive ground water monitoring program near their landfill and PCB-contaminated sludge pits and has found detectable levels of PCBs in groundwater, waste sludge and in the waste treatment system (IJC, 1982). Suspected sources of PCBs are presently being controlled and levels now entering the St. Lawrence River are believed to be insignificant.

Reynolds Metals Co. which operates an aluminum reduction plant, is also a major discharger to the St. Lawrence River at Massena New York. Its wastes are discharged through three separate outfalls consisting of a 4 MGD process water stream, a 2 MGD non-contact water stream and a 0.375 MGD sanitary sewage stream. NYSDEC sampled both process and intake waters and found no detectable levels of PCBs in September, 1980. Proposed permits (as of 1982) would restrict PCBs concentration in final effluents of Reynolds and General Motors to 1 ppb daily average, with a daily maximum of 2 ppb (IJC, 1982).

The Massena Sewage Treatment Plant (STP) discharges to the Grasse River. It is an upgraded secondary treatment facility which has not been in compliance with SPDES permit requirements and is currently under review by NYSDEC. New York does not require phosphorus removal or monitoring at municipal treatment facilities discharging to the St. Lawrence River (IJC, 1982).

4. RESULTS AND DISCUSSION

4.1 Point Source Inputs

4.1.1 Flow Rates

In terms of flow rate, the major point source dischargers along the Cornwall shoreline are Domtar Fine Papers and the Cornwall WPCP (Table 2). Their respective flow rates during the 1979 study period ranged from 142 x 10^3 to 144 x 10^3 m^3/d for Domtar and from 43 x 10^3 to 51 x 10^3 m^3/d for the Cornwall WPCP. The Courtaulds/BCL complex contributed an additional 15 x 10^3 to 17 x 10^3 m^3/d in flows (Appendix Table V).

4.1.2 Contaminants Loadings

Materials loadings presented in this section are gross loadings calculated using the mean effluent flow and mean contaminant concentration during the survey period.

TABLE 2

MEAN FLOW RATES ($10^3 m^3$/day) OF CORNWALL EFFLUENTS SAMPLED DURING THE 1979, 1980 and 1982 SURVEYS

Effluent	1979[a]	1980[b]	1982[c]
Domtar	142.28	116.68	128.21
CIL	2.37	3.09	3.57
Cornwall Chemicals	0.91	--	
Cornwall WPCP	45.03	45.55	47.22
Courtaulds/BCL acid	7.07	--	--
Courtaulds/BCL suplhate	1.90	--	--
Courtaulds/BCL viscose	7.33	--	--
Itea	0.09	--	--

Source: daily flow data in Appendix, Table V, VI, VII

(a) - Single survey, 4-day mean

(b) - Five surveys, 12-to 15-day mean

(c) - Two surveys, 6-day mean

"--" - Indicates no flow data; outfall was not sampled.

4.1.2.1 Conventional and Inorganic Contaminants*

With respect to loadings of conventional and inorganic contaminants (Table 3a), Domtar was the major contributor of total dissolved solids (TDC) (107,489 kg/d), suspended solids (SS) (16,753 kg/d), nitrite + nitrate (NO_2 + NO_3) (39 kg/d), chloride (21,875 kg/d), biological oxygen demand (BOD_5) (14,405 kg/d) and chemical oxygen demand (COD) (45,528 kg/d) to the river, whereas the Courtaulds/BCL acid and Courtaulds viscose sewers were the major source of sulphate (57,979 kg/d), sulphide (561 kg/d) and zinc (80 kg/d). Domtar's effluent was also the major source of fluoride (28 kg/d), cyanide (18 kg/d), aluminum (566 kg/d), cadmium (9.25 kg/d), chromium (9.96 kg/d), copper (10 kg/d), iron (184 kg/d) and lead (1.42 kg/d). The Cornwall WPCP and Domtar were the main dischargers of phosphorus (P) at 98 and 81 kg/d, respectively. While the Cornwall WPCP's final effluent concentration of total phosphorus was 2 mg P/L during the 1979 study, the phosphorus concentration is now averaging less than 1 mg P/L, due to improved removal efficiency (see section 3.1, page 25). Domtar and the Cornwall WPCP also contributed the majority of total Kjeldahl nitrogen (TKN) loadings (372 and 588 kg/day, respectively), and the WPCP was the largest source of ammonia (315 kg/day).

The pH of Courtaulds viscose sewer ranged from 10.8 to 11.9 in 1979 samples, while the Courtaulds/BCL acid sewer effluent was from 1.6 to 2.2. In contrast, the pH range of other Cornwall discharges was from 4.9 to 10.5.

CIL's mercury loading of 0.0635 kg/d was discharged to the river at a concentration of 0.4 ug/L after mixing with the Domtar and Cornwall Chemicals effluents. Assuming that these are representative of average conditions, this would be equivalent to 23 kg/year, which is in compliance with the regulation for chlor-alkali plants (0.0025 kg mercury per ton of chlorine produced per day) and represents a significant decline from a high of 590 kg/year in the early 1970's (MOE, 1977). Unexpectedly, mercury was also found in the other Cornwall effluents sampled in 1979, albeit at lower concentrations. Nevertheless, these contributed an additional 0.033 kg/d to the river (Table 3a). About 0.024 kg/d of this was from the Courtaulds/BCL sewers. Whether this is due to residual contamination of sewers or contaminants raw materials is unclear at present. The loading from the Cornwall WPCP in 1979 (0.0026 kg/d) was also substantially reduced to about 10% of earlier values (Pascoe, 1976).

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* Bacterial inputs are discussed in section 4.2.1.1 (page 36).

TABLE 3a
MEAN LOADINGS(*) (kg/day) OF NUTRIENTS, METALS AND OTHER CHEMICAL PARAMETERS FROM MAJOR DISCHARGERS TO THE ST. LAWRENCE RIVER AT CORNWALL, ONTARIO DURING THE 1979 SURVEY.

	Cornwall Chemicals	Domtar	CIL	Courtaulds/BCL sewers			Cornwall WPCP	ITEA (Celanese)
				sulphide	viscose	acid		
TP	0.35	81	0.36	0.18	0.93	1.10	98	0.03
$NO_2 + NO_3$	0.04	39	0.55	0.05	--	--	5.37	0.06
Ammonia	0.02	7.97	0.14	0.09	0.65	0.37	315	0.009
TKN	0.82	372	4.10	3.34	3.02	3.02	588	0.10
Chloride	284	21875	2973	1140	2090	853	5155	3.1
TDS	761	107489	5891	3530	17096	79932	33195	40
SS	19	16753	23	17	2764	304	3231	2.5
BOD_5	15	14405	1.66	685	1421	901	4671	7.5
COD	64	45528	152	1365	5059	2968	7317	21
Sulphate	182	16290	552	757	5030	52192	7013	4.6
Sulphide	3.52	4.27	X	69	319	173	--	--
Fluoride	0.64	28	1.60	0.48	1.65	1.94	21	0.05
Cyanide	0.0091	18	0.0178	X	X	X	3.60	X
Aluminum	0.17	566	0.96	0.11	0.59	7.24	38	0.02
Cadmium	0.0014	9.25	0.005	0.0042	X	X	0.12	0.0002
Chromium	0.01	9.96	0.01	0.04	0.75	0.35	1.80	0.0007
Copper	0.02	10	0.06	0.08	0.15	0.29	7.65	0.0005
Iron	1.19	184	3.96	2.37	5.28	28.27	32.98	0.09
Lead	X	1.42	0.09	0.13	0.57	1.02	0.0007	0.0009
Mercury	0.0008	0.0053	0.0635	0.0067	0.0095	0.0083	0.0026	X
Zinc	0.08	18.85	0.25	0.75	31.90	48.06	4.95	0.0018

Note:
* - Loadings based on 4 samples.
"X" - indicates loading was not quantifiable, since no detectable levels were found in any effluent samples.
"--" - indicates no data available.
TP - Total Phosphorus
$NO_2 + NO_3$-Nitrate and Nitrate

TKN - Total Kjeldahl Nitrogen
BOD - Biological Oxygen Demand
COD - Chemical Oxygen Demand
TDS - Total Dissolved Solids
SS - Suspended Solids

4.1.2.2 Organic Contaminants

Domtar was the major point source of total phenolics* to the Cornwall nearshore in 1979 (235 kg/d) and 1980 (116 kg/d). This facility also contributed the major portion of the 2,4,6-trichlorophenol (0.086 kg/d) and pentachlorophenol (0.186 kg/d) found in 1979 effluent samples (Table 3b).

Trace organic contaminants such as polychlorinated biphenyls (PCBs) and organochlorine pesticides were occasionally detected in the various plants' effluents, albeit at much lower concentrations than the previously-discussed contaminants. In view of the wide range of calculated loadings, these are expressed in mg/d in Table 3c, instead of kg/d. Domtar's effluent represented the highest loading of PCBs (an average of 37,156 mg/d for the 1979 and 1980 studies) from Ontario dischargers along the river. Domtar and the Cornwall WPCP were also the major contributors of many of the organochlorine pesticides (BHCs, chlordane, DDT and its metabolites, Thiodan and hexachlorobenzene), while the Courtaulds/BCL acid and Courtaulds acid sewers were important sources of BHC, endrin, heptachlor epoxide, Thiodan and hexachlorobenzene (HCB). The Cornwall WPCP was also the major point source of heptachlor epoxide during the 1979 survey. During the 1980 surveys, only PCBs, BHCs and HCB were detected in the WPCP effluent; however, the Domtar effluent still contained many of the organochlorine pesticides (and at similar loadings) detected in 1979. A direct comparison of trace organic loadings from the Ontario side of the river with those from the Massena area could not be made due to the lack of effluent data for sources along the New York shoreline during the two study periods. However, based on the PCB average daily limit of 1 ug/L proposed by NYSDEC for the major industrial sources in 1982 (see section 3.2) a total loading of 240,000 mg/d from all sources could be discharged to the river. This loading is about 3 times higher than the total arising from Ontario sources during the 1979 study period (69,924 mg/d).

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* 1980 phenolics inputs are also discussed in section 4.2.1.3 (pg. 58).

TABLE 3b

MEAN LOADINGS (kg/day) OF TOTAL PHENOLICS AND CHLORINATED PHENOLS FROM MAJOR DISCHARGERS TO THE ST. LAWRENCE RIVER AT CORNWALL, ONTARIO DURING 1979 and 1980 SURVEYS

	1979								1980		
	Cornwall Chemicals	Domtar	CIL	Courtaulds/BCL sewers			Cornwall WPCP	ITEA (Celanese)	Domtar	CIL/Cornwall Chemicals	Cornwall WPCP
				sulphate	viscose	acid					
Phenolics*	0.004(4)	235(4)	0.004 (4)	0.004 (4)	0.110(4)	0.030 (4)	2.12 (4)	0.002 (4)	116(12)	0.01(15)	0.64(15)
2,4,6-Trichlorophenol	X	0.086(2)	X	X	X	0.0003(2)	X	0.00004(2)	-	-	-
2,4,5-Trichlorophenol	X	X	X	X	X	X	X	0.0001 (2)	-	-	-
2,3,4-Trichlorophenol	X	X	X	X	X	X	X	X	-	-	-
Pentachlorophenol	0.009(1)	0.186(2)	0.0001(2)	0.0003(3)	0.006(2)	0.005 (2)	0.033(2)	0.0002 (2)	-	-	-

* - total phenolics as measured by the 4-aminoantipyrine method.

( ) - Figures in brackets indicate number of effluent samples analyzed.

"X" - indicates loading was not quantifiable, since detectable levels were not found in any samples.

"-" - indicates no data available.

TABLE 3c

MEAN LOADINGS* (mg/day) OF PCBs AND ORGANOCHLORINE PESTICIDES FROM MAJOR DISCHARGERS TO THE ST. LAWRENCE RIVER AT CORNWALL, ONTARIO DURING 1979 and 1980 SURVEYS

	1979							1980		
	Cornwall Chemicals	Domtar	CIL.	Courtaulds/BCL sewers			Cornwall WPCP	Domtar	CIL/Cornwall Chemicals	Cornwall WPCP
				sulphate	viscose	acid				
PCBs	146	57977	1673	372	587	389	8780	16335	340	400
Aldrin	X	X	X	X	X	X	X	X	X	X
Dieldrin	X	X	1.19	X	X	1.77	X	X	21	X
alpha-BHC	X	249	X	2.85	11	27	56	182	8	168
beta-BHC	X	142	X	X	X	X	79	324	12	48
gamma-BHC (Lindane)	X	249	X	12	X	X	90	272	5	355
alpha-Chlordane	X	36	X	X	X	X	225	X	0.34	X
gamma-Chlordane	X	36	X	X	X	X	X	130	X	X
o,p-DDT	X	X	X	X	X	X	X	130	X	X
p,p-DDT	X	X	2.97	19	X	X	225	X	2	X
p,p-DDE	0.23	818	18	0.48	1.83	3.53	56	1115	30	X
p,p-DDD	X	178	2.96	2.38	X	X	248	X	X	X
Endrin	X	X	X	0.48	X	212	23	X	5	X
Heptachlor	X	X	X	X	X	X	X	X	X	X
Heptachlor epoxide	0.23	X	0.59	0.48	53	27	979	195	3	X
HCB	X	783	5.93	X	18	1.77	11	1024	188	304
Thiodan I	X	36	X	1.43	55	35	146	X	X	X
Thiodan II	X	X	X	1.43	128	X	675	X	3	X
Mirex	X	X	X	X	X	X	X	X	X	X

* - Loadings are based on 4 samples during 1979 survey. During 1980, 3 samples were obtained at the Cornwall WPCP; 9 samples each were collected at Domtar and CIL/Cornwall Chemicals.

"X" - indicates loading was not quantifiable, since no detectable levels were found in any effluent samples.

PCBs - polychlorinated biphenyls

HCB - Hexachlorobenzene

Gas chromatographic/mass spectrometric (GC/MS) analyses identified a large variety of additional non-volatile base-neutral and acid-extractable organic compounds in the Cornwall effluents sampled in 1979 (Table 16, pg. 106). However, these compounds could not be accurately quantitated, and therefore no loading calculations were attempted. Nevertheless, the detection of compounds on the MOE list of materials requiring further evaluation and/or the USEPA priority pollutants list (i.e. nitrobenzene, dischlorobenzene, trichlorobenzene, naphthalene, nitronaphthalene, benzothiazole, phenol, cresol, diethyl-, dibutyl- and dioctyl phthalate) is noteworthy. Also, some of these are related to specific industrial sources or processes.

4.1.3 Point Source vs. Urban Runoff Loadings

It should be noted that municipal and industrial point source discharges alone do not constitute the totality of contaminant inputs into an urban area such as Cornwall. Atmospheric deposition and subsequent urban runoff is another potentially important source. While urban runoff was not measured or analyzed during the 1979 and 1982 surveys, this aspect was examined during the fall of 1980 by Environment Canada (Wong, 1981). Assuming similar meteorological and point source input conditions, a comparison of selected 1979 point source data (Tables 2, 3a, 3b and 3c) with the urban runoff information of 1980 was made. As summarized below, total municipal and industrial sources can exceed urban runoff by a considerable amount:

	(a) 1979 Point source	(b) 1980 Urban runoff	(a)/(b)
Flow, m^3/day	206,890	10,904	19
Solids, kg/day	23,115	751	31
PCBs, mg/day	69,924	1,260	55
Organochlorine pesticides, mg/day	5,170	467	11
Metals, g/day	151,092	10.0	15,109

The above comparison suggests that direct discharge of industrial and municipal effluents, and not urban runoff, constitutes the major source of the inorganic and organic contaminants considered.

4.2 Ambient (River) Studies

Discussion of the ambient data is organized into the respective media sampled during the studies, i.e. water, sediments and biota. An attempt is also made to elucidate a cause-effect relationship, i.e., the interaction and mobilization of pollutants from sediments to water and biota.

4.2.1 Water Quality

4.2.1.1 Conventional Contaminants

4.2.1.1.1 Bacteria

Densities of fecal coliforms in water have been related to the presence of sewage or fecal matter and therefore to the potential risk of contracting disease. As a result, fecal coliform bacteria have been used as indicators of bacteriological water quality. A potential health hazard exists and water quality is considered impaired if the fecal coliform geometric mean density for a series of water samples exceeds 100 organisms/100 mL (MOE, 1978).

The fecal coliform test enumerates Escherichia coli (E. coli), Enterobacter, Citrobacter and Klebsiella. Of these, only E. coli is considered to be fecal specific. Sources of the other fecal coliform organisms in waters uncontaminated by human or animal wastes include soil, air and natural proliferation in nutrient-enriched aquatic environments. Klebsiella have also been shown to thrive in pulp and paper mill effluents (Vlassoff, 1977). Consequently, high levels of fecal coliforms may not necessarily be an indication of sewage or fecal contamination if the majority of the organisms enumerated by the fecal coliform test are not E. coli.

An attempt to speciate fecal coliforms with respect to E. coli and Klebsiella was made during the 1982 study. However, it has since been shown that the testing procedures used to identify these organisms were unreliable.

Pseudomonas aeruginosa is most likely to be found in bathing areas impacted by high human activity. It causes skin rashes and eye infections and is the organism most frequently associated with ear infections. A relationship has been developed between Pseudomonas levels in bathing waters and the risk of contracting ear infections.

Fecal streptococci are another indicator of bacteriological water quality. They are usually used in conjunction with fecal coliforms as an indication of the original fecal contamination (MOE, 1978). However, the use of fecal coliforms to fecal streptococci ratios as a means of differentiating between animal and human fecal origin has not always proven to be very reliable.

The geometric mean concentrations of fecal coliform bacteria in St. Lawrence River surface waters at Cornwall, Ontario during 1980 are shown in Figures 5-9. During the July, September and October surveys, river water samples from nearshore stations as far as 8 km downriver of the Domtar/CIL/Cornwall Chemicals diffuser outfall exceeded the Provincial Water Quality Objective (PWQO) of 100 organisms/100 mL for the protection of waters used for body contact recreation (MOE, 1978). The highest geometric mean densities (up to 26,134/100 mL) occurred immediately downstream of this outfall (Appendix, Table VIII). Water samples collected from immediately downstream of Courtaulds/BCL were also found to be in excess of this objective in November. The August 6-9, 1982 survey results for fecal coliforms (Figures 10 and 11) confirm the 1980 results, with high densities still being observed downstream of the Domtar/CIL/Cornwall chemicals diffuser outfall (stations 054 to 056). Densities above the PWQO were also observed further downriver, at the beginning of Lake St. Francis and near South Lancaster (i.e. stations 070E and 070B which are not shown in Figures 10 and 11 (see Figure 4 and Appendix, Table XIII).

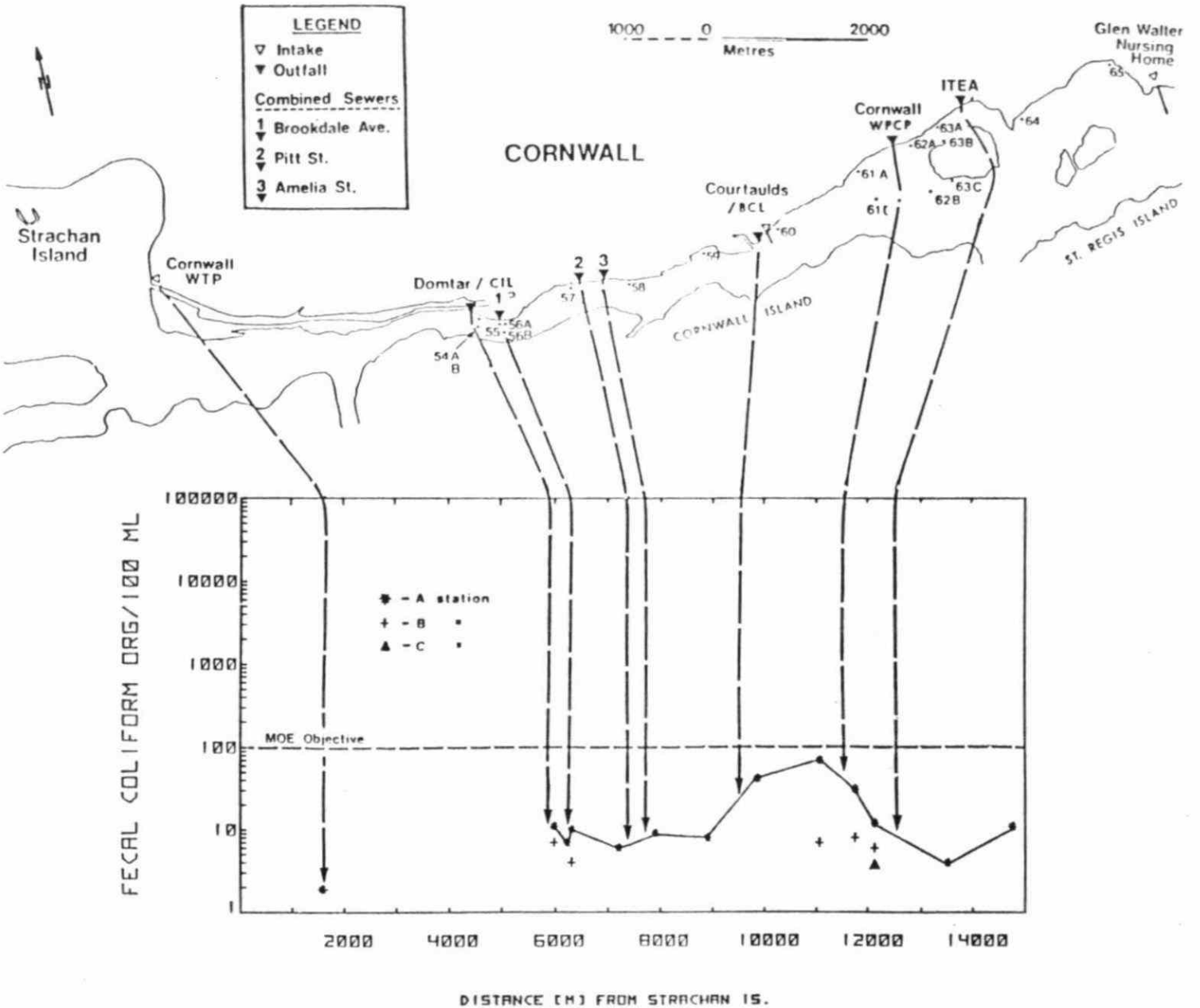

FIG 5. Geometric Mean Fecal Coliform Concentrations (organisms/100 ml.) in St. Lawrence River surface waters (1.5 m. depth), June 24 – 26, 1980.

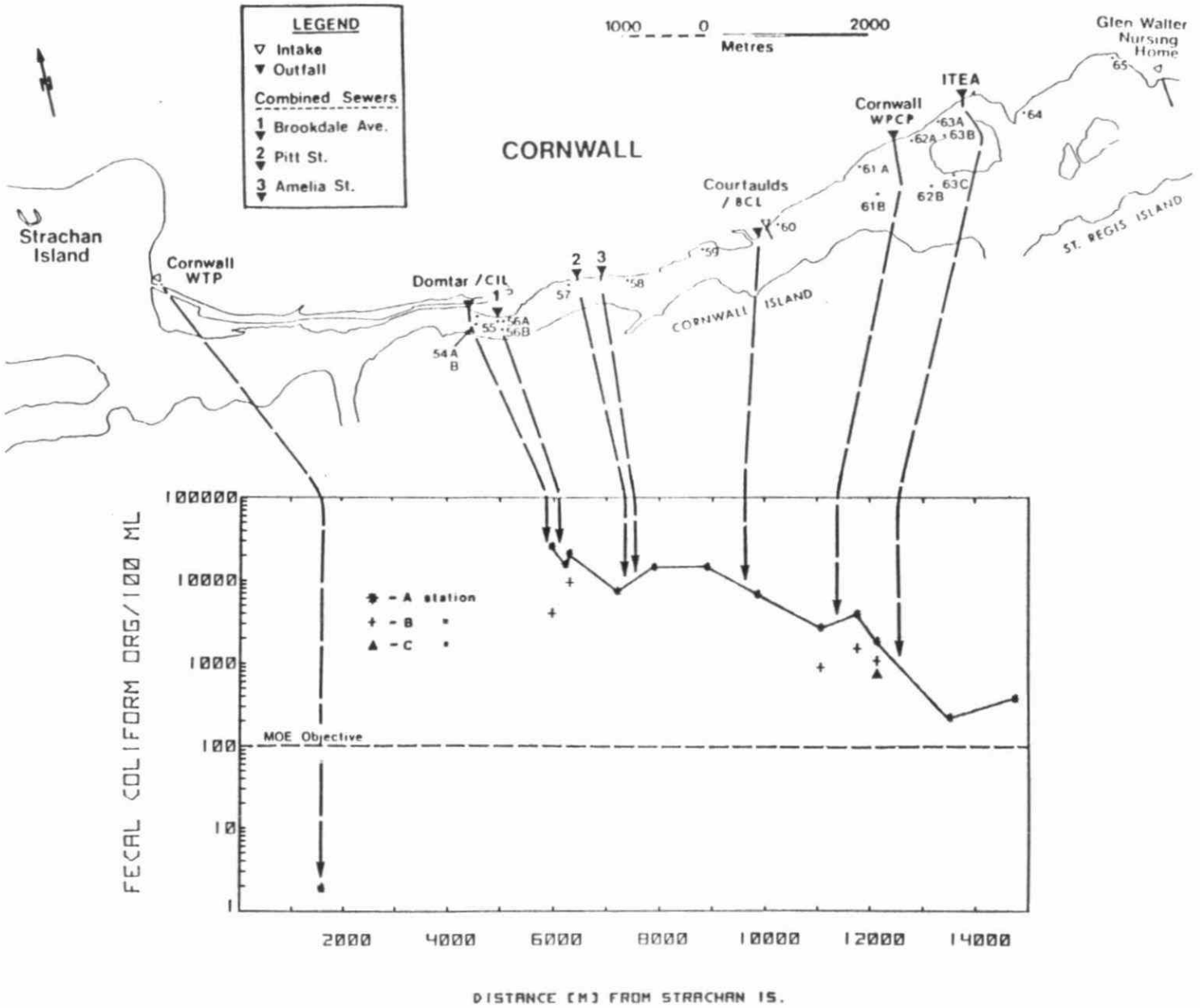

FIG 6. Geometric Mean Fecal Coliform Concentrations (organisms/100 ml.) in St. Lawrence River surface waters (1.5 m. depth), July 29 - 31, 1980.

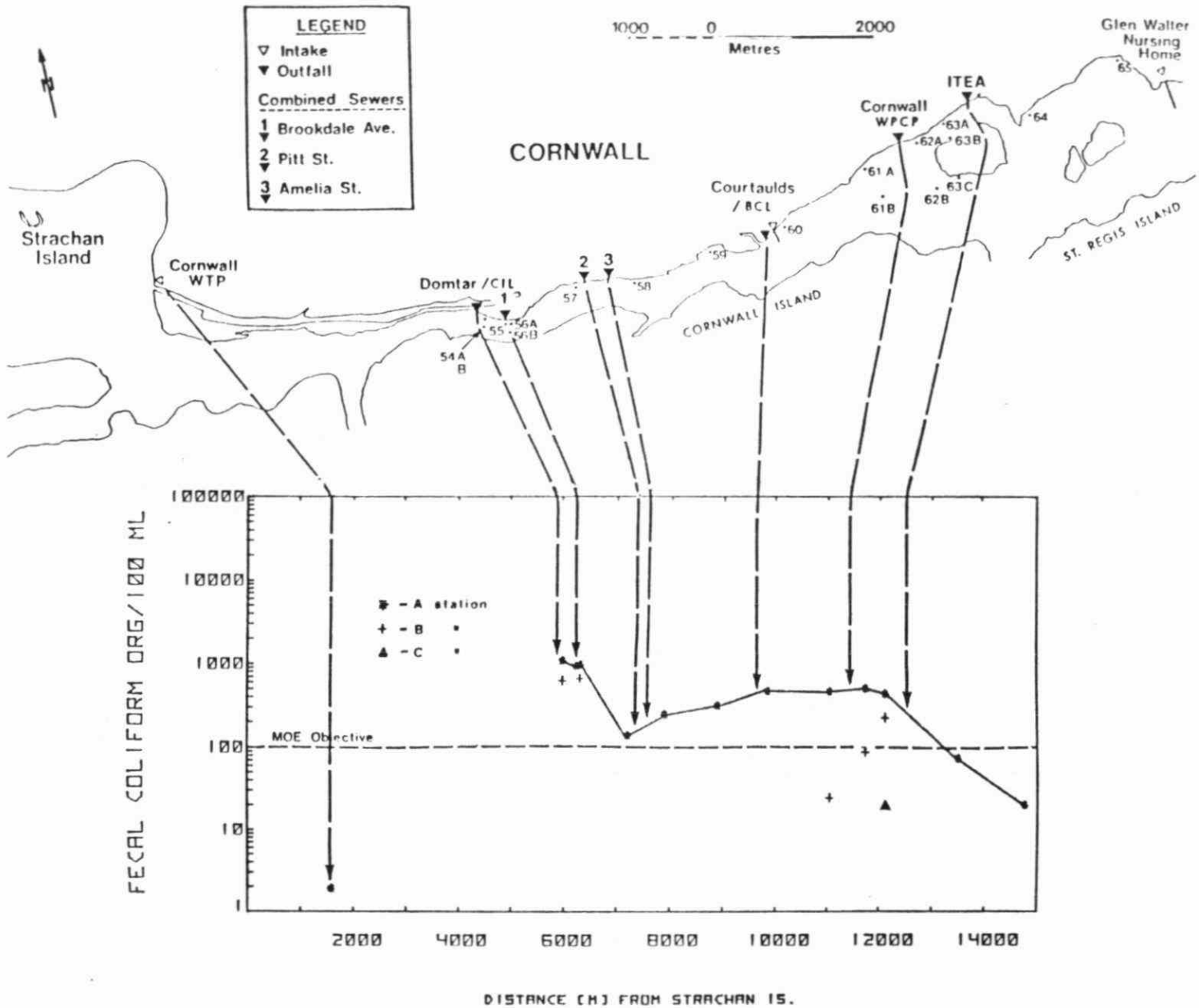

FIG 7. Geometric Mean Fecal Coliform Concentrations (organisms/100 ml.) in St. Lawrence River surface waters (1.5 m. depth), Sept. 9 - 11, 1980.

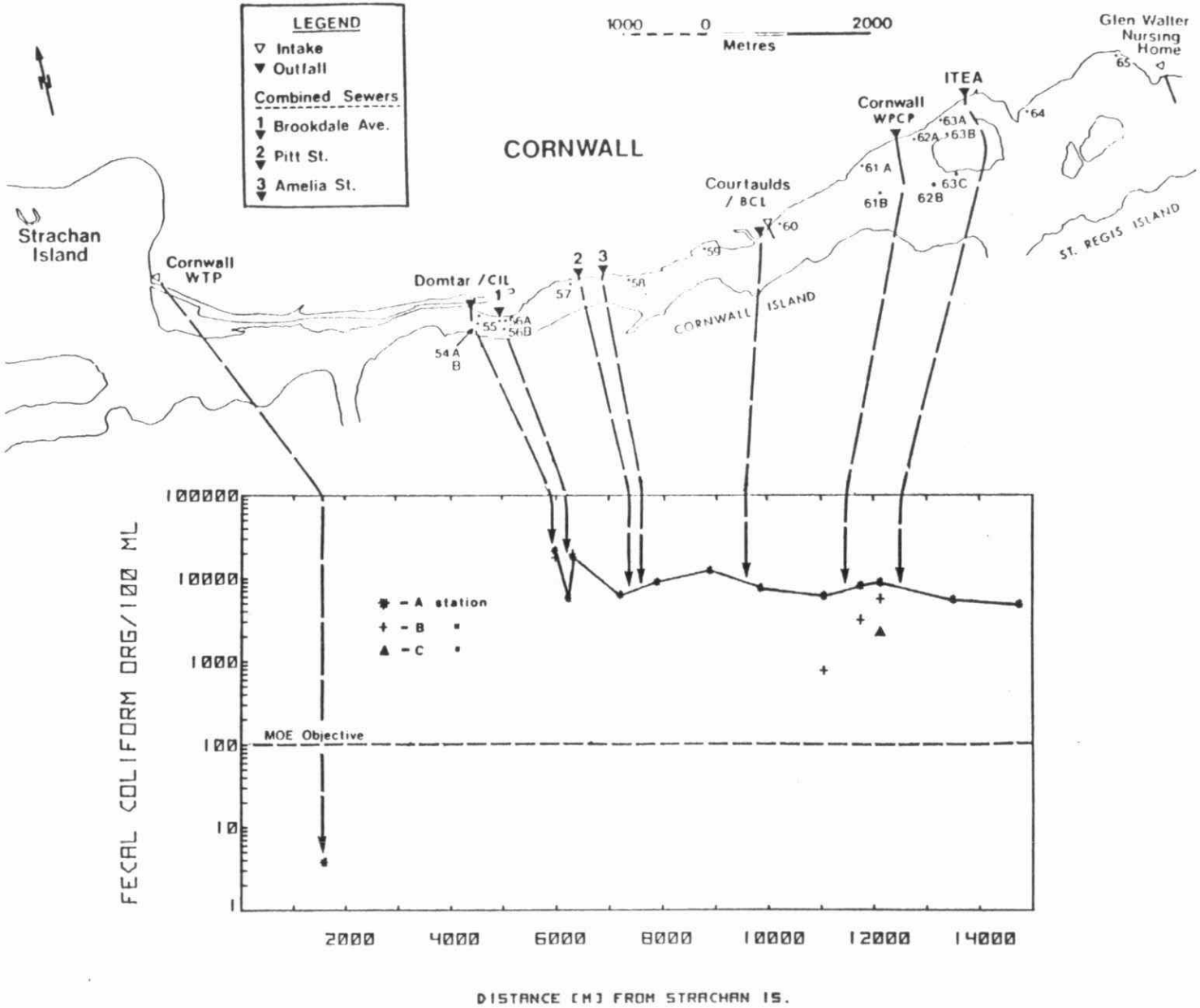

FIG 8. Geometric Mean Fecal Coliform Concentrations (organisms/100 ml.) in St. Lawrence River surface waters (1.5 m. depth), Oct. 21 - 23, 1980.

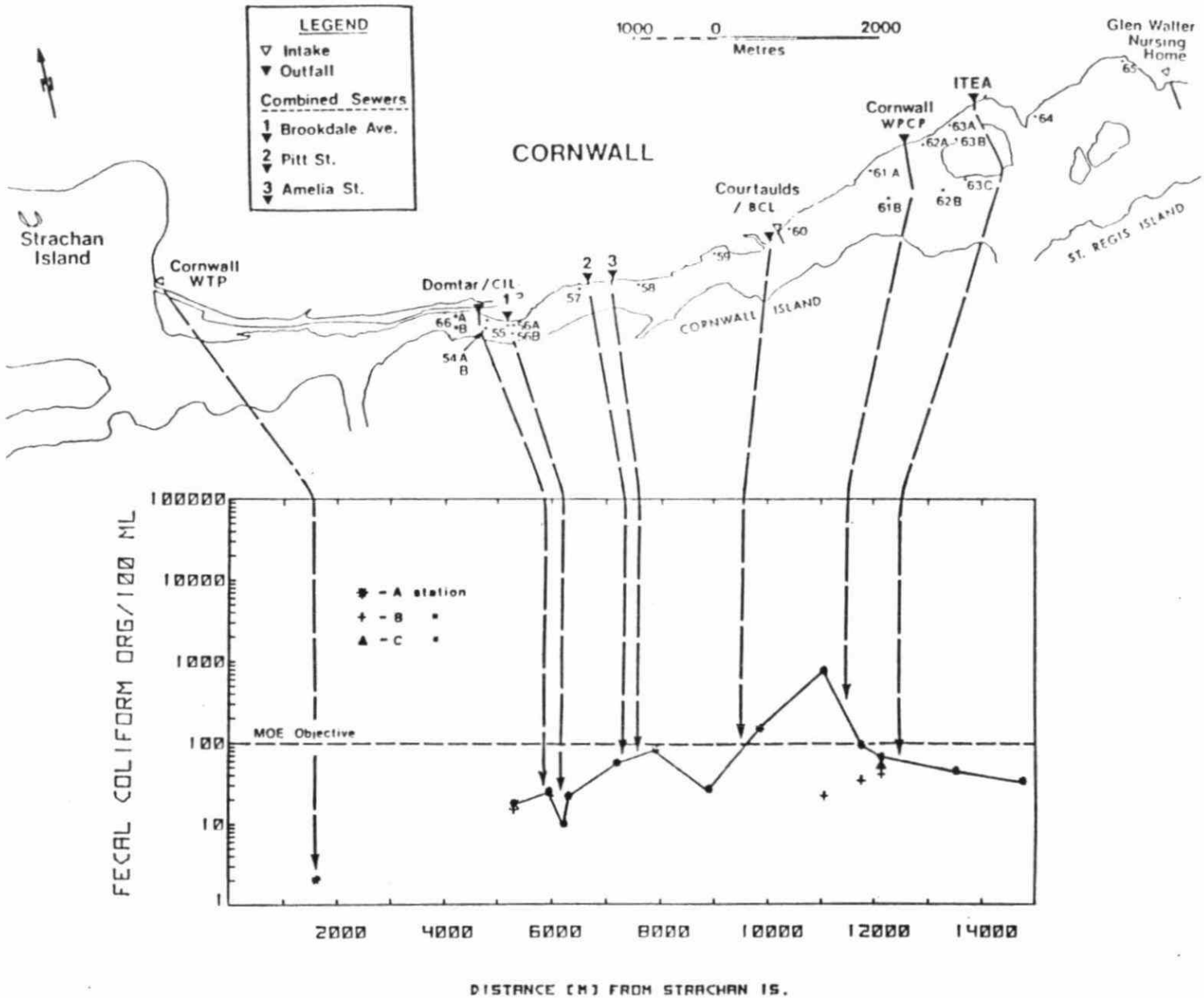

FIG 9. Geometric Mean Fecal Coliform Concentrations (organisms/100 ml.) in St. Lawrence River surface waters (1.5 m. depth), Nov. 25 – 27, 1980.

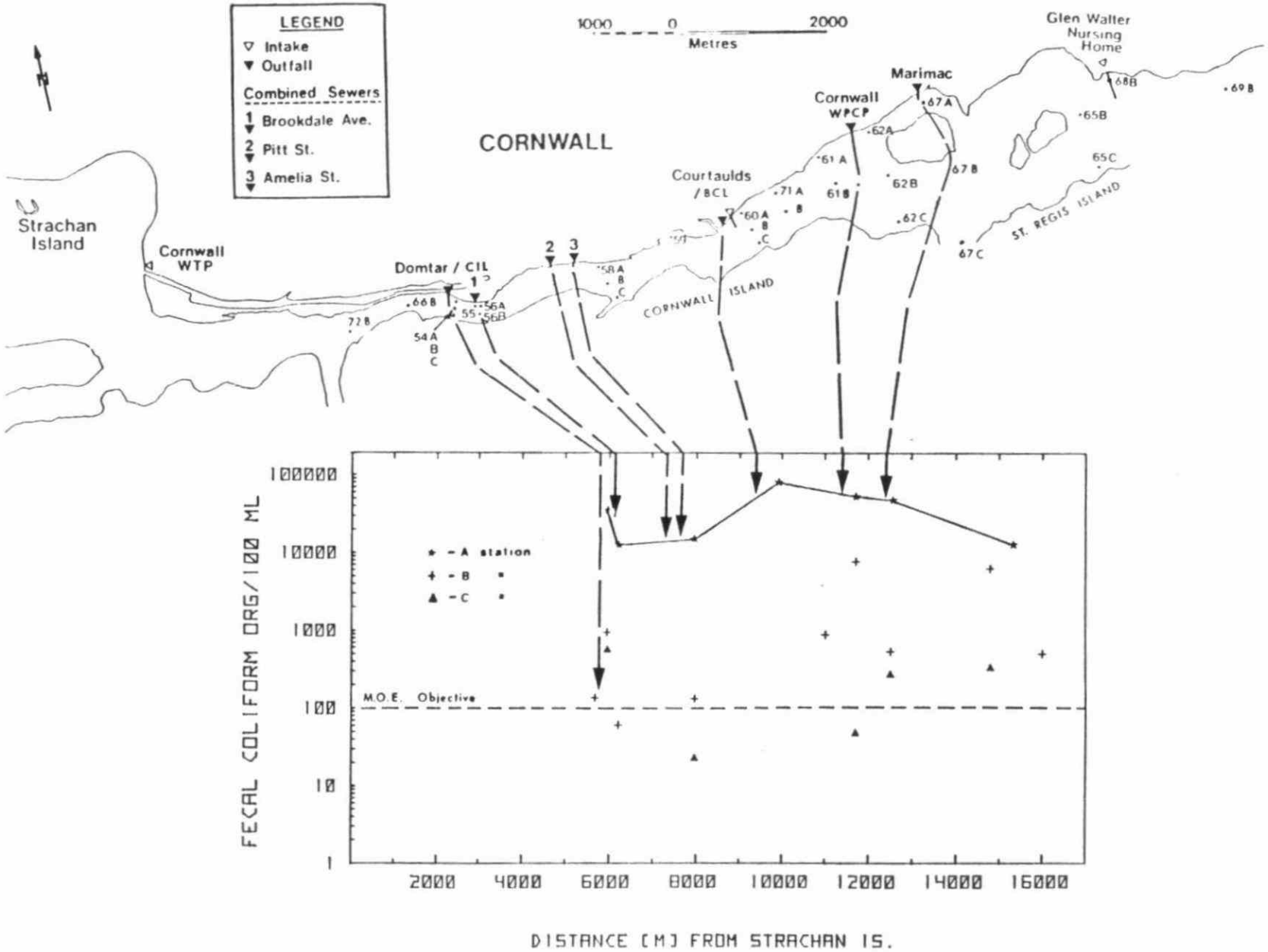

FIG. 10 Geometric Mean Fecal Coliform Concentrations (organisms/100 ml.) in St. Lawrence River surface waters (1.5 m. depth), Aug. 6 - 9, 1982

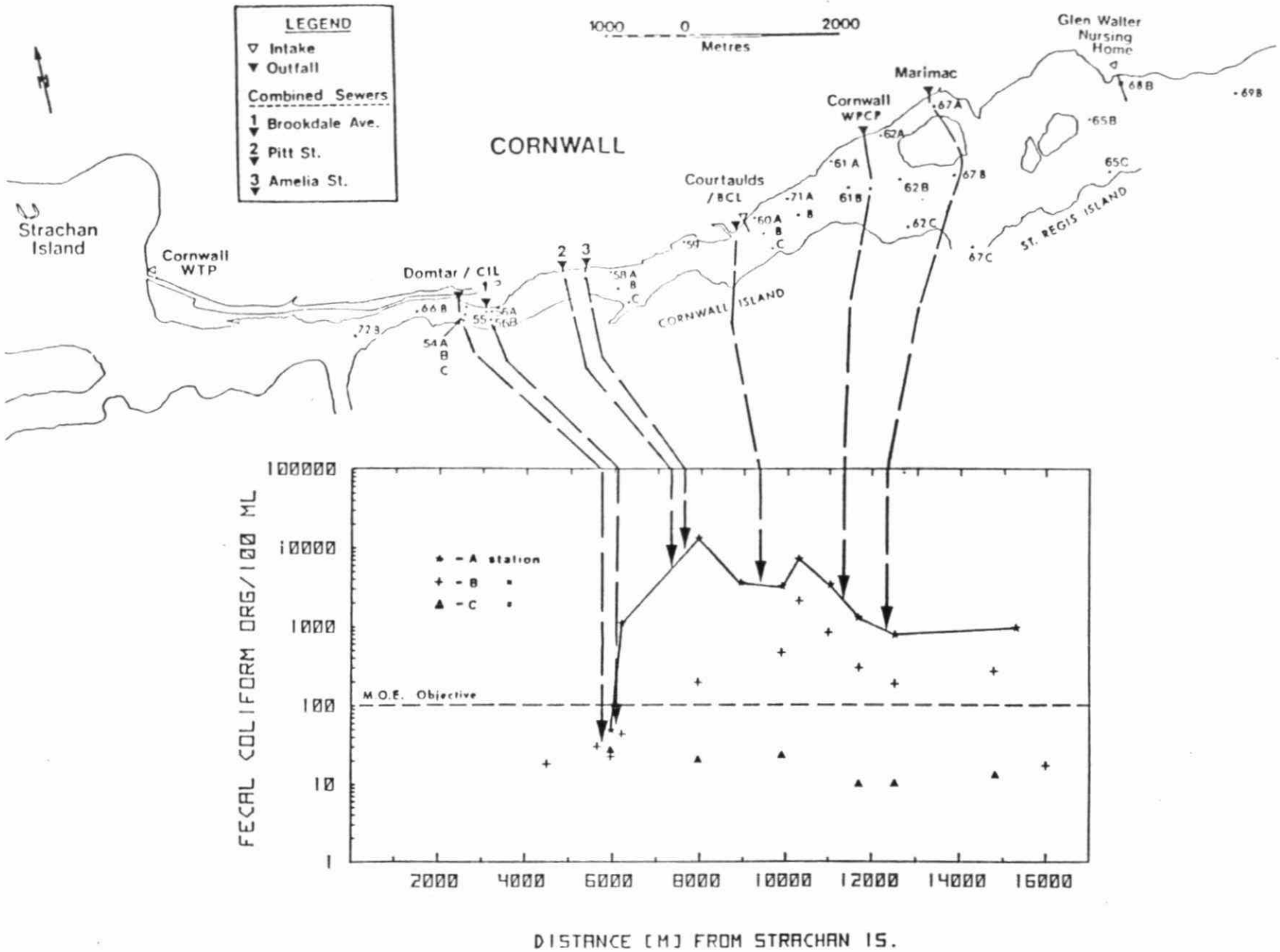

FIG. 11 Geometric Mean Fecal Coliform Concentrations (organisms/100 ml.) in St. Lawrence River surface waters (1.5 m. depth), Sept. 28-30, 1982

In general, fecal Streptococcus and Pseudomonas aeruginosa densities (Appendix, Tables IX, X, XIV) did not follow a similar distribution pattern to that noted for fecal coliforms (Appendix, Tables VIII, XI). Mean concentrations of these organisms remained relatively low at all stations. However, mean densities of fecal Streptoccoccus were somewhat higher in July, 1980 than during the other surveys and this may be related to the higher densities in the Domtar and Cornwall WPCP effluents at that time (Appendix, Table XI).

Fecal coliform densities in the final effluents of Domtar, CIL/Cornwall Chemicals and the Cornwall WPCP during the 1980 surveys are presented in Table 4; those for the 1982 surveys appear in Table 5. The results show that densities in the Domtar effluent generally exceeded those from other sources, and, combined with its much higher flow rate, suggests that Domtar Fine Papers was the major contributor of fecal coliforms to the surface waters of the St. Lawrence River at Cornwall during the two studies. Geometric mean concentrations of the Domtar final effluent during the five 1980 and two 1982 surveys were 41,664 organisms/100 mL and 11,164,193 organisms/100 mL, respectively.

The effect of the Domtar effluent on bacterial numbers was further illustrated by the dramatic decline in fecal coliform densities observed in downstream surface water samples taken when the Domtar mill was shut down in November 1980 and also in June when both effluent flow rate and fecal coliform densities were lower (Appendix, Table VI). Also, river flow rates during the five survey periods did not vary in a manner which would have led to less dilution of the effluent during those surveys with the highest bacterial densities (Appendix, Tables IV and VI). Although fecal coliform densities were quite high in the Cornwall WPCP effluent during July 1980 and September 1982, there was little downstream impact from this source (see Figures 6 and 11), possibly because of its much lower flow (Table 2, page 29). Nevertheless, these high final effluent densities suggest inadequate chlorination of municipal wastes.

TABLE 4
FECAL COLIFORM CONCENTRATIONS (organism/100 mL) IN CORNWALL
INFLUENT AND FINAL EFFLUENTS SAMPLED DURING 1980 SURVEYS

Sampling Date		Cornwall WTP(raw)	Domtar	CIL	Brookdale Ave. combined sewer	Cornwall WPCP
June	24	<2	<10	<10	-	-
	25	-	< 4	< 4	-	>600
	26	-	≃80	<10	-	>15,000
	Gm	-	<10	<10	-	>7,800
July	29	2	4,000,000	7,900	60,000*	6,000,000
	30	-	24,000,000	140,000	-	3,000
	31	-	32,000,000	≃100	-	41,000,000
	Gm	-	14,536,965	33,257	-	903,689
September	9	<2	>15,000	<10	-	2,000
	10	-	>15,000	150	-	250
	11	-	>15,000	230	-	<10
	Gm	-	>15,000	186	-	707
October	21	4	700,000	<100	-	120
	22	-	2,900,000	< 10	-	<100
	23	-	1,300,000	<100	-	<100
	Gm	-	1,381,910	<100	-	<10
November	25	<2	-	<10	-	260
	26	-	-	<10	-	2,100
	27	-	-	<10	-	<10
	Gm	-	-	<10	-	739

Gm = Geometric Mean
* = Only sampled during overflow event
"-" = No sample (or not calculated). Note: Domtar shut down during November survey.

Cornwall WTP raw water data courtesy of J. Bates, City of Cornwall.

However, high fecal coliform densities during 1982 in the vicinity of the Courtaulds/BCL complex (stations 059, 060 and downstream) indicate additional bacterial inputs in this area (see Figures 10 and 11). The high densities at station 059A on September 29 (41,000/100 mL) and station 060A on August 9 (240,000/100 mL) appear to be correlated to rainfall events during the preceeding 24 to 48 hours (Appendix, Tables III and XIII). This suggests storm water runoff or combined sewer overflows. This may also explain elevations in fecal coliform densities in this area on some of the 1980 survey days (see Figures 5 and 9 and Appendix Tables II and VIII).

4.2.1.1.2 Nutrients and Major Ions

Data on ambient water samples collected in 1979 are summarized in Tables 6a, b, c, d, e, f, along with available objectives for the protection of aquatic life. From this, it is evident that waters at the mouths of the major tributaries are chemically different from the main river water. The Grasse, Raquette and St. Regis Rivers are characterized by lower chloride, sulphate, conductivity and pH and higher nutrient and metals (i.e. aluminum and iron) concentrations relative to upriver (e.g. Cornwall WTP raw water) levels. Stations located downstream of industrial inputs were also characterized by elevated nutrients, sulphate, conductivity (a measure of total dissolved solids) and metals in water samples (see Figure 12). This is reflective of the known loadings of these parameters from point source discharges (see Table 3a). Chan (1980) found similar spatial differences and concentrations of nutrients in 1977 water samples from this area.

4.2.1.2 Inorganic Contaminants

Some of the inorganics tested for in 1979 water samples (i.e. cyanide, chromium, lead) were not found in water samples with the then-available detection limits. However, the results (Tables 6e and 6f) indicate that concentrations of cadmium, copper, iron, mercury and zinc were detected in excess of GLWQA and PWQO objectives for the protection of aquatic life on at least one occasion at several locations.

TABLE 5
BACTERIAL CONCENTRATIONS (organisms/100mL) IN
CORNWALL FINAL EFFLUENTS SAMPLED DURING 1982 SURVEYS

Sampling Date		Domtar		CIL/Cornwall Chemicals		Cornwall WPCP	
		FC	FS	FC	FS	FC	FS
August	6	40,000,000	1,500	<10	<100	24,000	4,900
	7	62,000,000	600	200	∿100	2,400	1,100
	8	40,000,000	2,500	∿30	<100	200	1,100
	9	10,000,000	-	∿300	∿200	∿700	10,000
	Gm	31,559,340	1,310	≤65	≤119	∿1,685	2,775
September	28	400,000	1,400	<100	<100	>15,000	23,000
	29	14,000,000	5,700	<100	<100	120,000	∿7,000
	30	11,000,000	4,800	∿200	<100	∿10,000	∿2,000
	Gm	3,949,362	3,371	≤126	<100	≥12,247	∿6,854

Gm = Geometric Mean
FC = Fecal coliform
FS = Fecal Streptococcus
" - " indicates no data available.

Concentrations of iron exceeded the water quality objective (0.3 mg/L) at the mouths of the Grasse, Raquette and St. Regis Rivers (Figure 13). Mean concentrations were 0.39, 0.31 and 0.45 mg/L, respectively at these sites. These values were well above the concentration at the upstream control (0.05 mg/L) and were similar to those observed in 1977 (Chan, 1980).

Concentrations of aluminum (Figure 13) in the vicinity of the Grasse River mouth (station 033) and the Reynolds Metals and General Motors discharges were detected at concentrations (0.13 mg/L to 0.28 mg/L) above the upstream river control station (0.06 mg/L). Chan (1980) also noted elevated aluminum levels at the Grasse River mouth in 1977.

Filtered mercury only exceeded the water quality objective of 0.2 ug/L in a small percentage of the samples taken from the mouths of the St. Regis (12%) and Grasse (14%) Rivers. These single-sample exceedences had concentrations of 1.30 ug/L and 0.16 ug/L, respectively.

The objective for zinc (0.03 mg/L) was exceeded in 25% of the samples taken from the vicinity of the Raquette River mouth. Maximum concentrations were 0.04 mg/L. Although one sample of Cornwall WTP raw water contained 0.94 mg/L zinc, the major area of objective exceedences was near the Courtaulds/BCL complex (station 094), where levels ranged from 0.08 mg/L to 0.18 mg/L in three samples.

The method detection limits for cyanide, cadmium and copper were above the respective water quality objectives. Nevertheless, some samples contained detectable concentrations of cadmium and copper. Along the north shore, cadmium was only detected in one out of four samples at the Cornwall WTP (0.007 mg/L). Similar levels were found along the south shore (0.005 mg/L to 0.009 mg/L) although the frequency of detection and exceedence of the 0.0002 mg/L objective was greater at the tributary mouths (42% to 62% of samples) than in the vicinity of the Reynolds Metals and General Motors discharges (33%).

Copper was detected above the water quality objective of 0.005 mg/L in two of three samples (at 0.02 mg/L) near the Courtaulds/BCL complex (station 094). Detections along the south shore were at the mouths of the major tributaries, with concentrations ranging from 0.02 mg/L to 0.06 mg/L and the highest frequency of exceedence (42%) being at the mouth of the Grasse River.

In view of the above-noted differences between detection limits and water quality objectives, the percentage exceedences for copper and cadmium should be considered as minima until analysis of samples using lower detection levels is carried out.

TABLE 6a

PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERIZATION OF RIVER WATER SAMPLES COLLECTED FROM THE NORTH SHORE OF THE ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	Chloride (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Suspended Solids (mg/L)	Total Diss. Solids (mg/L)	Chorophyll a (µg/L)	Chlorophyll b (µg/L)	Chlorophyll a corr. (µg/L)	Conductivity @ 25°C (µs/cm)	pH	Dissolved Oxygen (mg/L)	Temperature °C	Secchi Depth (m)
Stn. 112 (Control)	Oct. 2	27.0	29.0	0.1	4	208	2.9	0.6	2.1	320	8.03	9.10	16.8	-
Cornwall WTP	Sept. 21	27.0	27.5	0.1	0.2	208	-	-	-	320	8.00	-	18.0	-
	Sept. 25	26.5	26.5	0.1	-	-	-	-	-	320	7.90	-	18.0	-
	Sept. 26	27.0	27.5	0.1	-	-	-	-	-	315	7.10	-	19.0	-
	Sept. 28	26.5	27.5	0.1	-	-	-	-	-	310	7.60	-	18.0	-
Cornwall Canal	Sept. 25	31.5	30.5	0.1	2	218	4.4	0.8	3.5	336	7.70	10.10	16.8	2.0
	Sept. 26	27.5	32.0	0.2	3	211	5.2	0.8	4.0	325	8.38	10.90	17.0	1.8
	Sept. 27	26.5	29.5	0.2	1	211	5.5	0.8	4.5	325	8.31	10.90	16.5	1.8
Stn. 104	Oct. 10	27.5	29.0	0.1	2	200	3.4	1.3	2.8	308	7.50	8.30	14.0	-
Stn. 094	Sept. 24	32.5	63.0	0.1	-	-	3.6	0.9	2.9	420	8.50	-	-	0.3
	Sept. 25	37.5	54.0	0.2	32	247	2.6	1.4	1.7	380	9.00	8.40	17.5	0.2
	Sept. 26	29.5	47.5	0.2	3	234	4.0	1.0	3.3	360	8.20	8.80	17.0	1.8
Stn. 095	Oct. 12	28.0	31.0	0.1	2	213	2.4	0.9	1.8	328	7.86	8.50	13.8	-
Farlinger's Pt. Stn. 071	Oct. 13	28.0	30.5	0.1	2	213	2.7	0.8	1.9	328	7.23	9.10	13.2	-
Raisin River Stn. 055	Sept. 27	24.0	36.5	0.1	3	-	3.6	0.7	3.1	348	-	-	-	-
Stn. 057	Sept. 27	26.5	29.5	0.1	-	-	1.7	0.9	1.1	320	8.33	10.40	16.0	2.2
Water Quality Objective:	GLWQA PWQO			1.2		200					>6.5+ <9.0 >6.5+ <8.5	>6.0 >6.0	<10°C increase	

NOTES: 1) "-" indicates no sample or no analytical result

2) * as unionized ammonia; percentages of total varies with temperature and pH

3) ** free cyanide.

TABLE 6b
PHYSICAL, CHEMICAL AND BIOLOGICAL CHARACTERIZATION OF RIVER WATER SAMPLES
COLLECTED FROM THE SOUTH SHORE OF THE ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	Chloride (mg/L)	Sulphate (mg/L)	Fluoride (mg/L)	Suspended Solids (mg/L)	Total Diss. Solids (mg/L)	Chorophyll a (µg/L)	Chlorophyll b (µg/L)	Chlorophyll a corr. (µg/L)	Conductivity @ 25°C (µs/cm)	pH	Dissolved Oxygen (mg/L)	Temperature °C	Secchi Depth (m)
Grasse River														
Stn. 002	Sept. 20	2.95	17.0	0.2	3	68	1.1	0.4	0.4	104	-	-	16.0	1.2
	Sept. 21	3.65	19.0	0.3	-	-	2.5	0.8	1.7	115	6.78	8.40	17.8	1.2
	Sept. 22	3.30	19.5	0.3	-	-	1.2	0.9	0.3	118	6.83	8.40	16.0	1.4
	Sept. 23	8.35	21.5	0.3	-	-	3.1	0.9	2.3	165	6.81	8.20	14.9	1.2
	Sept. 24	9.15	21.5	0.3	-	-	2.5	1.1	1.9	175	7.92	8.60	14.9	1.7
	Sept. 25	4.80	21.0	0.4	-	-	1.4	0.7	0.8	138	7.05	8.70	15.2	1.3
	Sept. 27	5.95	21.0	0.4	-	-	1.3	0.9	0.6	155	7.35	8.20	15.2	1.8
Stn. 033	Oct. 3	21.0	26.5	0.3	10	176	4.2	0.4	2.7	270	7.12	8.50	16.4	-
Reynolds Metals	Sept. 21	26.5	54.0	0.4	-	-	3.4	1.2	3.2	388	8.18	9.20	18.8	2.0
	Sept. 25	26.5	29.0	0.2	3	205	2.8	1.0	2.0	315	7.87	8.80	16.9	2.0
	Sept. 26	26.5	30.5	0.4	3	208	2.7	0.8	2.2	320	8.38	9.60	17.0	1.8
General Motors	Sept. 21	26.0	28.5	0.1	-	-	3.6	1.4	3.4	315	7.47	9.40	18.5	2.0
	Sept. 25	27.0	29.0	0.1	2	208	2.2	0.9	1.2	320	7.93	9.20	16.8	2.0
	Sept. 26	27.0	28.0	0.2	3	207	3.0	1.0	2.7	318	8.35	10.20	17.0	2.0
Raquette River														
Stn. 003	Sept. 20	2.55	15.0	0.1	1	64	1.2	0.3	0.6	98	6.20	-	15.5	1.6
	Sept. 21	4.80	15.5	0.1	-	-	1.2	0.7	0.5	119	6.32	9.70	16.5	1.5
	Sept. 22	14.50	21.0	0.1	-	-	1.1	0.8	0.5	208	6.91	8.60	16.2	1.3
	Sept. 23	2.15	13.0	0.1	-	-	1.4	0.9	1.0	86	-	9.10	15.5	2.2
	Sept. 24	1.95	10.5	0.1	-	-	1.4	1.1	0.7	72	6.94	9.80	15.1	1.8
	Sept. 25	2.10	10.5	0.1	-	-	6.3	1.2	5.0	73	7.02	9.70	15.0	1.5
	Sept. 27	1.65	9.0	0.1	-	-	20.4	0.8	17.2	60	7.22	9.30	15.5	2.0
	Oct. 4	2.50	9.5	<.01	1	56	2.6	0.6	1.4	86	-	-	-	-
St. Regis River														
Stn. 068	Sept. 20	1.75	13.5	0.1	2	46	1.5	0.5	1.0	71	6.60	-	14.6	-
	Sept. 21	1.95	13.0	0.1	-	-	1.5	0.7	-	77	6.36	10.00	14.9	1.3
	Sept. 22	1.75	12.5	0.1	-	-	1.1	0.9	0.6	82	6.43	10.10	13.8	1.5
	Sept. 23	1.75	12.5	0.1	-	-	1.2	0.7	0.7	77	-	8.90	14.8	1.1
	Sept. 24	1.75	12.0	0.1	-	-	1.2	1.2	0.9	77	6.82	10.40	15.2	1.6
	Sept. 25	1.85	12.0	0.1	-	-	1.0	0.7	0.4	78	7.22	9.60	14.2	1.4
	Sept. 27	1.80	11.0	0.1	-	-	1.1	0.6	0.6	80	7.27	9.50	14.9	1.5
	Oct. 5	2.40	10.0	<0.1	7	65	3.5	0.7	1.4	100	-	-	-	-
Salmon River														
Stn. 060	Sept. 26	7.8	16.0	0.1	-	-	1.7	0.7	1.1	178	7.43	9.90	14.5	1.5
Water Quality Objective:	GLWQA			1.2		200					>6.5-<9.0	>6.0	<10°C increase	
	PWQO										>6.5-<8.5	>6.0		

NOTES: 1) "-" indicates no sample or no analytical result
2) * as unionized ammonia; percentages of total varies with temperature and pH.
3) ** free cyanide.

TABLE 6c

NUTRIENT CONCENTRATIONS IN RIVER WATER SAMPLES COLLECTED FROM THE NORTH SHORE OF THE ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	Total Phosphorus (mg/L)	Filtered T.P. (µg/L)	F.R.P. (mg/L)	$NO_2 + NO_3$ (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Total Carbon (mg/L)	Total Organic Carbon (mg/L)
Stn. 112 (Control)	Oct. 2	.024	12.8	.001	.005	.004	.30	10.0	7.8
Cornwall WTP	Sept. 21	.026	-	.011	.195	.010	.22	-	-
	Sept. 25	.025	-	.008	.170	.006	.22	-	-
	Sept. 26	.022	-	.003	.170	<.001	.20	-	-
	Sept. 28	.021	-	.006	-	.018	.19	-	-
Cornwall Canal	Sept. 25	.022	10.9	.004	.040	<.001	.34	-	-
	Sept. 26	.025	13.3	.004	.030	<.001	.32	-	-
	Sept. 27	.028	12.2	.005	.050	.016	.29	-	-
Stn. 104	Oct. 10	.021	16.8	.008	.115	.054	.31	23.9	2.5
Stn. 094	Sept. 24	.124	102.0	.074	.025	.008	.40	-	-
	Sept. 25	.053	37.0	.033	.045	.006	.33	-	-
	Sept. 26	-	26.0	.008	.036	<.001	-	-	-
Stn. 095	Oct. 12	.037	13.4	.015	.515	.053	.60	58.2	35.0
Farlinger's Pt. Stn. 071	Oct. 13	.016	15.2	.007	.120	.044	.29	24.0	2.6
Raisin River									
Stn. 055	Sept. 27	.021	16.0	.002	.095	.010	.42	-	-
Stn. 057	Sept. 27	.016	13.5	.004	.040	.026	.28	-	-
Water Quality Objective:	GLWQA					.020*			
	PWQO	.030				.020*			

NOTES: 1) "-" indicates no sample or no analytical result

2) * as unionized ammonia; percentages of total varies with temperature and pH.

3) ** free cyanide.

TABLE 6d
NUTRIENT CONCENTRATIONS IN RIVER WATER SAMPLES COLLECTED FROM THE SOUTH SHORE OF THE ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	Total Phosphorus (mg/L)	Filtered T.P. (µg/L)	F.R.P. (mg/L)	$NO_2 + NO_3$ (mg/L)	Ammonia (mg/L)	TKN (mg/L)	Total Carbon (mg/L)	Total Organic Carbon (mg/L)
Grasse River Stn. 002	Sept. 20	.054	41.0	.001	.110	.069	.67	-	-
	Sept. 21	.047	34.0	.032	.110	.068	.68	-	-
	Sept. 22	.060	40.0	.031	.114	.068	.68	-	-
	Sept. 23	.050	30.0	.022	.114	.067	.65	-	-
	Sept. 24	.039	33.0	.015	.099	.051	.54	-	-
	Sept. 25	.041	37.0	.019	.114	.071	.62	-	-
	Sept. 27	.056	41.0	.017	-	.082	.64	-	-
Stn. 033	Oct. 3	.050	22.0	.001	.005	.008	.38	41.8	23.0
Reynolds Metals	Sept. 21	.027	20.0	.007	.100	.038	.39	-	-
	Sept. 25	.024	21.0	.008	.094	.026	.29	-	-
	Sept. 26	.029	14.4	.007	.094	.024	.33	-	-
General Motors	Sept. 21	.021	18.0	.014	.105	.031	.29	-	-
	Sept. 25	.021	13.9	.009	.139	.022	.35	-	-
	Sept. 26	.014	15.6	.007	.089	.024	.27	-	-
Raquette River Stn. 003	Sept. 20	.022	14.8	.001	.165	.024	.47	-	-
	Sept. 21	.018	17.0	.006	.145	.019	.41	-	-
	Sept. 22	.020	15.4	.004	.144	.016	.42	-	-
	Sept. 23	.019	14.2	.006	.134	.019	.38	-	-
	Sept. 24	.016	10.4	.003	.124	.018	.31	-	-
	Sept. 25	.019	10.2	.009	.144	.028	.32	-	-
	Sept. 27	.158	16.6	.059	.140	.016	.30	-	-
	Oct. 4	.021	12.7	.004	.230	.002	.32	8.9	5.3
St. Regis River Stn. 068	Sept. 20	.032	25.0	.002	.060	.021	.58	-	-
	Sept. 21	.030	25.0	.011	.060	.015	.52	-	-
	Sept. 22	.047	26.0	.028	.065	.013	.48	-	-
	Sept. 23	.032	25.0	.015	.055	.024	.46	-	-
	Sept. 24	.031	24.0	.012	.055	.012	.44	-	-
	Sept. 25	.043	23.0	.017	.050	.010	.41	-	-
	Sept. 27	.038	27.0	.014	.055	.014	.39	-	-
	Oct. 5	.066	37.0	.034	.110	.004	.38	14.4	7.0
Salmon River Stn. 060	Sept. 26	.022	23.0	.007	.119	.018	.40	-	-
Water Quality Objective:	GLWQA					.020*			
	PWQO	.030				.020*			

NOTES: 1) "-" indicates no sample or no analytical result
2) * as unionized ammonia; percentages of total varies with temperature and pH
3) ** free cyanide.

TABLE 6e
INORGANIC TRACE CONTAMINANTS CONCENTRATIONS IN RIVER WATER SAMPLES COLLECTED FROM THE NORTH SHORE OF THE ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	Cyanide (mg/L)	Aluminum (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Lead (mg/L)	Mercury (µg/L)	Filtered Mercury (µg/L)	Zinc (mg/L)
Stn. 112 (Control)	Oct. 2	-	.06	.006	<.02	<0.01	.05	<.03	0.15	0.04	.01
Cornwall WTP	Sept. 21	<.01	<.02	.007	<.02	<.01	.10	<.03	<.03	-	.02
	Sept. 25	<.01	<.02	<.005	<.02	<.01	.13	.06	<.02	-	.02
	Sept. 26	<.01	<.02	<.005	.02	<.01	.18	<.03	<.02	-	.02
	Sept. 28	<.01	<.02	<.005	<.02	<.01	.14	<.03	<.02	-	.94
Cornwall Canal	Sept. 25	<.01	.04	<.005	<.02	<.01	.05	<.03	.04	0.04	<.01
	Sept. 26	<.01	.04	<.005	<.02	<.01	.05	<.03	.02	0.06	<.01
	Sept. 27	<.01	.04	<.005	<.02	<.01	<.02	<.03	.05	0.02	.02
Stn. 104	Oct. 10	-	-	-	-	-	-	-	-	-	-
Stn. 094	Sept. 24	-	.14	<.005	<.02	.02	.24	<.03	.20	-	.18
	Sept. 25	<.01	.04	<.005	<.02	<.01	.06	<.03	.13	0.06	.08
	Sept. 26	<.01	.08	<.005	<.02	.02	.05	<.03	.10	0.13	.10
Stn. 095	Oct. 12	-	-	-	-	-	-	-	-	-	-
Farlinger's Point Stn. 071	Oct. 13	-	-	-	-	-	-	-	-	-	-
Raisin River											
Stn. 055	Sept. 27	<.01	.08	<.020	<.005	<0.01	.08	<.03	0.04	0.02	.01
Stn. 057	Sept. 27	<.01	<.02	<.020	<.005	<0.01	<.02	<.03	0.03	0.03	.02
Water Quality Objective:	GLWQA			.0002	.100	.005	.30	.025		0.2	.03
	PWQO	.005**		.0002	.050	.005	.30	.025		0.2	.03

NOTES: 1) "-" indicates no sample or no analytical result
2) * as unionized ammonia; percentages of total varies with temperature and pH
3) ** free cyanide.

TABLE 6f

INORGANIC TRACE CONTAMINANTS CONCENTRATIONS IN RIVER WATER SAMPLES COLLECTED FROM THE SOUTH SHORE OF THE ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	Cyanide (mg/L)	Aluminum (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Copper (mg/L)	Iron (mg/L)	Lead (mg/L)	Mercury (µg/L)	Filtered Mercury (µg/L)	Zinc (mg/L)
Grasse River Stn. 002	Sept. 20	<0.01	.16	.009	<.02	.02	.35	<.03	.11	.16	.02
	Sept. 21	<0.02	.16	.006	<.02	<.01	.35	<.03	<.03	<.03	<.01
	Sept. 22	<0.01	.04	.007	<.02	.02	.35	<.03	.06	.02	<.01
	Sept. 23	<0.01	.10	<.005	<.02	.06	.36	<.03	.02	.02	<.01
	Sept. 24	<0.01	.14	<.005	.03	<.01	.46	<.03	.09	.02	<.01
	Sept. 25	<0.01	.16	<.005	<.02	<.01	.40	<.03	.02	<.02	<.01
	Sept. 27	<0.01	.18	<.005	<.02	<.01	.47	<.03	.02	.03	<.01
Stn. 033	Oct. 3	<.01	.28	.008	<.02	0.02	.36	<.03	0.32	0.24	.04
Reynolds Metals	Sept. 21	<.01	.26	.008	<.02	<.01	.16	<.03	<.03	<.03	<.01
	Sept. 25	<.01	.06	<.005	<.02	<.01	.10	<.03	.05	<.02	.02
	Sept. 26	<.01	.08	.005	<.02	<.01	.08	<.03	.03	.07	<.01
General Motors	Sept. 21	<.01	.75	.006	<.02	<.01	.27	<.03	.08	<.03	<.01
	Sept. 25	<.01	.02	<.005	<.02	<.01	.09	<.03	.02	<.02	<.01
	Sept. 26	<.01	.05	<.005	<.02	<.01	.06	<.03	<.02	.06	<.01
Raquette River Stn. 003	Sept. 20	<0.01	.06	.006	<.02	<.01	.28	<.03	.03	.05	<.01
	Sept. 21	<0.01	.12	.006	<.02	.03	.28	<.03	<.03	<.03	.04
	Sept. 22	<0.01	.16	.007	<.02	<.01	.39	<.03	<.02	.03	.02
	Sept. 23	<0.01	.05	<.005	<.02	<.01	.22	<.03	<.02	<.02	<.01
	Sept. 24	<0.01	<.02	.005	<.02	<.01	.20	<.03	.02	.02	<.01
	Sept. 25	<0.01	<.02	<.005	.02	.02	.42	<.03	.02	<.02	.04
	Sept. 27	<0.01	.05	<.005	<.02	.02	.30	<.03	.03	.04	<.01
	Oct. 4	<0.01	.07	.007	<.02	<.01	.36	<.03	.04	.06	.02
St. Regis River Stn. 068	Sept. 20	<0.01	.15	.008	<.02	<.01	.45	<.03	.03	<.03	<.01
	Sept. 21	<0.01	.07	.006	<.02	<.01	.48	<.03	<.03	<.03	<.01
	Sept. 22	<0.01	<.02	.006	<.02	.02	.50	<.03	.02	.04	.02
	Sept. 23	<0.01	.16	<.005	<.02	<.01	.52	<.03	<.02	.03	<.01
	Sept. 24	<0.01	<.02	<.005	<.02	<.01	.48	<.03	.02	<.02	<.01
	Sept. 25	<0.01	<.02	<.005	<.02	<.01	.17	<.03	<.02	.03	.02
	Sept. 27	<0.01	.06	<.005	<.02	<.01	.45	<.03	.03	.02	<.01
	Oct. 5	<0.01	.14	.008	<.02	<.01	.54	<.03	.04	1.30	.02
Salmon River Stn. 060	Sept. 26	-	.04	<.005	<.020	<0.01	.30	<.03	0.04	0.06	.01
Water Quality Objective:	GLWQA			.0002	.100	.005	.30	.025		0.2	.03
	PWQO	.005**		.0002	.050	.005	.30	.025		0.2	.03

NOTES: 1) "-" indicates no sample or no analytical result
2) * as unionized ammonia; percentages of total varies with temperature and pH
3) ** free cyanide.

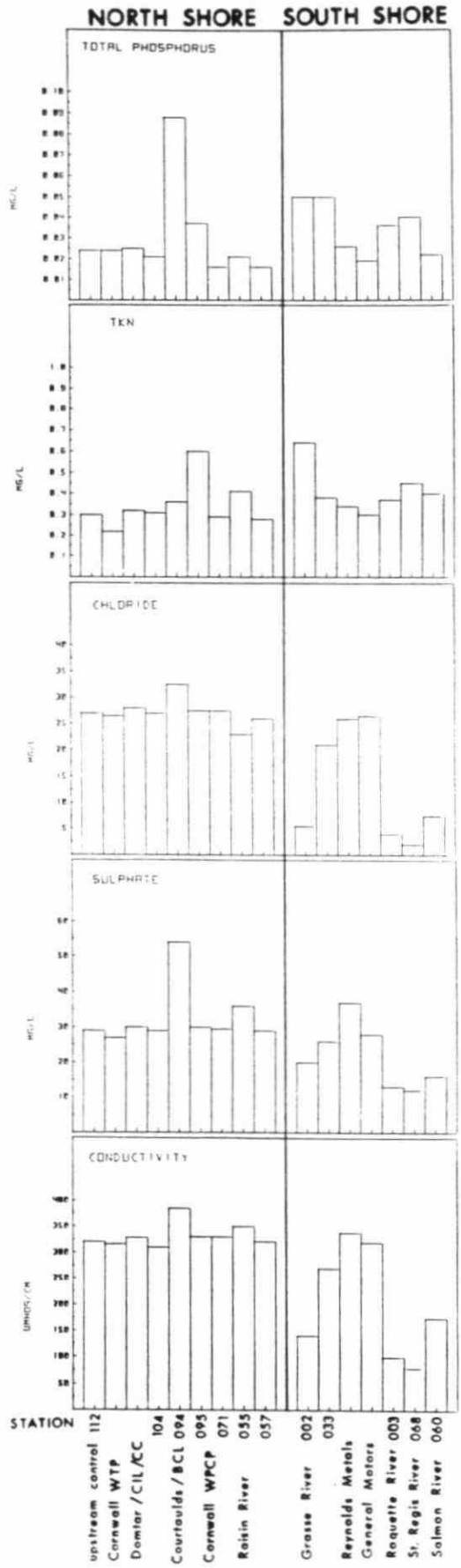

FIG. 12 Total phosporus, total kjeldahl nitrogen, chloride, sulphate and conductivity in St. Lawrence River waters (mid-depth), 1979

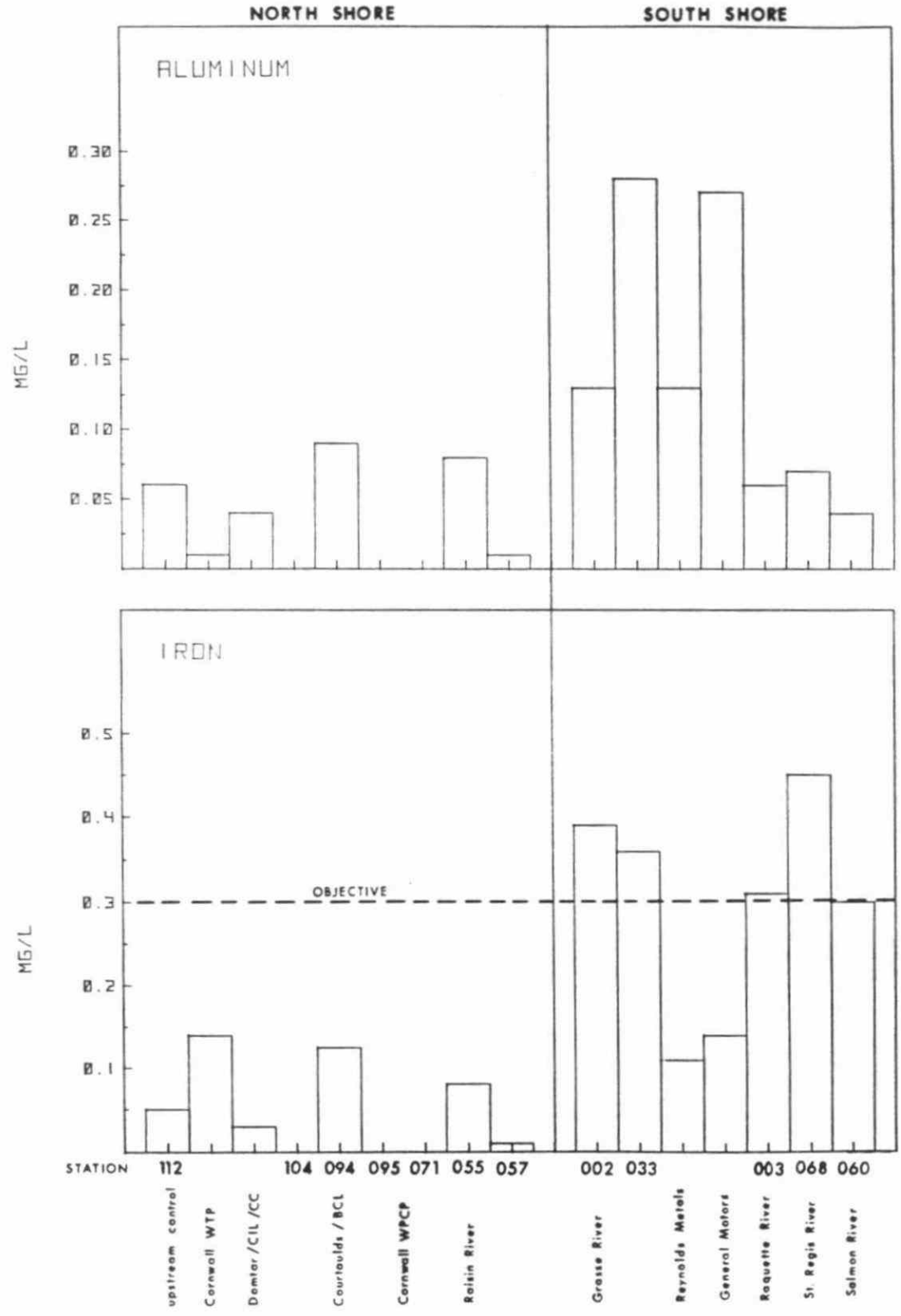

FIG. 13 Total aluminum and total iron content of St. Lawrence River waters (mid-depth), 1979

4.2.1.3 Organic Contaminants

4.2.1.3.1 Phenolics

Sampling during 1979 revealed the presence of phenolics in Ontario nearshore waters (range = 1 to 5 ug/L), occasionally above the Provincial Water Quality (PWQO) and Great Lakes Water Quality Agreement (GLWQA) objectives of 1 ug/L (Tables 7a and 7b). Phenolics were also occasionally detected in New York waters, at levels from 1 to 2 ug/L.

Chlorinated phenols were also found in some surface water samples. As with phenolics, levels were highest downstream of Domtar and in the vicinity of Courtaulds/BCL. The compounds identified were the same as those found in some Cornwall effluent samples - 2,4,6-trichlorophenol and pentachlorophenol. Although 2,4,6-trichlorophenol was only found in one sample at 0.08 ug/L, pentachlorophenol was detected in samples from the Cornwall WTP raw water intake (0.20 ug/L) to as far downstream as the mouth of the Raisin River (1.20 ug/L). Pentachlorophenol was also found in some water samples from the mouths of the Grasse, Raquette and St. Regis Rivers and near the Reynolds Metals and General Motors outfalls at concentrations from 0.20 ug/L to 1.20 ug/L. The PWQO and/or the proposed GLWQA objectives of 0.5 and 0.4 ug/L, respectively, were exceeded, on at least one occasion, at stations 094 and 057 (Raisin River) on the north shore of the river and at the Grasse river mouth (Stn. 033), Reynolds Metals and General Motors outfalls on the south side.

The concentrations of total phenolics in surface waters along the Ontario side of the river during 1980 are depicted in Figures 14-18. The highest concentrations of phenolics (up to 23 ug/L - Appendix Table XIII) occurred at sampling sites near the Domtar/CIL/Cornwall Chemical combined outfall, with concentrations decreasing downriver. During the July, September and October surveys, phenolic concentrations were above the GLWQA and PWQO of 1 ug/L* for a distance of about 8 km below this outfall. In June and November, however, no violations of the objective were detected. These two survey periods corresponded to lower effluent flow and phenolics concentrations (June) and a shut-down of the mill (November).

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* to protect against taste and odour problems in domestic water supplies and to prevent the tainting of fish.

TABLE 7a

PHENOLICS, CHLOROPHENOL AND PHENOXY HERBICIDE CONCENTRATRATIONS (µg/L) IN RIVER WATER SAMPLES COLLECTED FROM THE NORTH SHORE OF THE ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	Phenolics (4 AAP)*	2,4-D	2,4,5-T	2,4-DB	Silvex	2,4,6-Trichlorophenol	2,4,5-Trichlorophenol	2,3,4-Trichlorophenol	Pentachlorophenol
Cornwall										
Stn. 112 (Control)	Oct. 2	<1	X	X	X	X	X	X	X	X
Cornwall WTP	Sept. 21	1	X	X	X	X	X	X	X	0.20
	Sept. 25	1	-	-	-	-	-	-	-	-
	Sept. 26	1	-	-	-	-	-	-	-	-
	Sept. 28	1	-	-	-	-	-	-	-	-
Cornwall Canal	Sept. 25	1	-	-	-	-	-	-	-	-
	Sept. 26	<1	X	X	X	X	X	X	X	0.20
	Sept. 27	<1	X	X	X	X	X	X	X	-
Stn. 104	Oct. 10	4	X	X	X	X	X	X	X	X
Stn. 094	Sept. 24	3	X	X	X	X	X	X	X	X
	Sept. 25	3	-	-	-	-	-	-	-	-
	Sept. 26	5	X	X	X	X	X	X	X	1.12
Stn. 095	Oct. 12	4	X	X	X	X	X	X	X	X
Stn. 071	Oct. 13	4	X	X	X	X	0.08	X	X	0.10
Stn. 055	Sept. 27	<1	-	-	-	-	-	-	-	-
Stn. 057	Sept. 27	1	X	X	X	X	X	X	X	1.20
Detection Limit		1	0.10	0.05	0.20	0.05	0.05	0.05	0.10	0.05
Water Quality Objectives:	GLWQA	1	-	-	-	-				0.4**
	PWQO	1	4	-	-	-		18		0.5

" - " indicates no sample or no analytical result

* Total Phenol measured as phenol by 4-Aminoantipyrene method.

** Recommended objective.

x Not detected

TABLE 7b
PHENOLICS, CHLOROPHENOL AND PHENOXY HERBICIDE CONCENTRATIONS (µg/L)
IN RIVER WATER SAMPLES COLLECTED FROM THE SOUTH SHORE OF THE
ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	Phenolics (4 AAP)*	2,4-D	2,4,5-T	2,4-DB	Silvex	2,4,6-Trichlorophenol	2,4,5-Trichlorophenol	2,3,4-Trichlorophenol	Pentachlorophenol
Grasse River										
Stn. 002	Sept. 20	<1	X	X	X	X	X	X	X	0.20
	Sept. 21	<1	X	X	X	X	X	X	X	0.38
	Sept. 22	<1	X	X	X	X	X	X	X	X
	Sept. 23	<1	X	X	X	X	X	X	X	X
	Sept. 24	<1	X	X	X	X	X	X	X	X
	Sept. 25	1	-	-	-	-	-	-	-	-
	Sept. 27	<1	X	X	X	X	X	X	X	X
Stn. 033	Oct. 3	1	X	X	X	X	X	X	X	1.20
Reynolds Metals	Sept. 21	<1	X	X	X	X	X	X	X	0.30
	Sept. 25	1	-	-	-	-	-	-	-	-
	Sept. 26	<1	X	X	X	X	X	X	X	0.44
General Motors	Sept. 21	<1	X	X	X	X	X	X	X	0.40
	Sept. 25	2	X	X	X	X	X	X	X	0.06
	Sept. 26	2	-	-	-	-	-	-	-	-
Raquette River										
Stn. 003	Sept. 20	<1	X	X	X	X	X	X	X	0.07
	Sept. 21	<1	X	X	X	X	X	X	X	0.30
	Sept. 22	<1	X	X	X	X	X	X	X	X
	Sept. 23	<1	X	X	X	X	X	X	X	X
Stn. 003	Sept. 24	<1	X	X	X	X	X	X	X	X
	Sept. 25	1	-	-	-	-	-	-	-	-
	Sept. 27	1	X	X	X	X	X	X	X	X
	Oct. 4	<1	X	X	X	X	X	X	X	X
St. Regis River										
Stn. 068	Sept. 20	<1	X	X	X	X	X	X	X	0.07
	Sept. 21	<1	X	X	X	X	X	X	X	X
	Sept. 22	<1	X	X	X	X	X	X	X	X
	Sept. 23	<1	X	X	X	X	X	X	X	X
	Sept. 24	<1	X	X	X	X	X	X	X	X
	Sept. 25	1	-	-	-	-	-	-	-	-
	Sept. 27	1	X	X	X	X	X	X	X	X
	Oct. 5	1	X	X	X	X	X	X	X	X
Salmon River										
Stn. 060	Sept. 26	<1	X	X	X	X	X	X	X	0.13
Detection Limit		1	0.10	0.05	0.20	0.05	0.05	0.05	0.10	0.05
Water Quality	GLWQA	1	-	-	-	-				0.4**
Objectives:	PWQO	1	4	-	-	-		18		0.5

" - " indicates no sample or no analytical result
* Total Phenol measured as phenol by 4-Aminoantipyrene method.
** Recommended objective
x Not detected

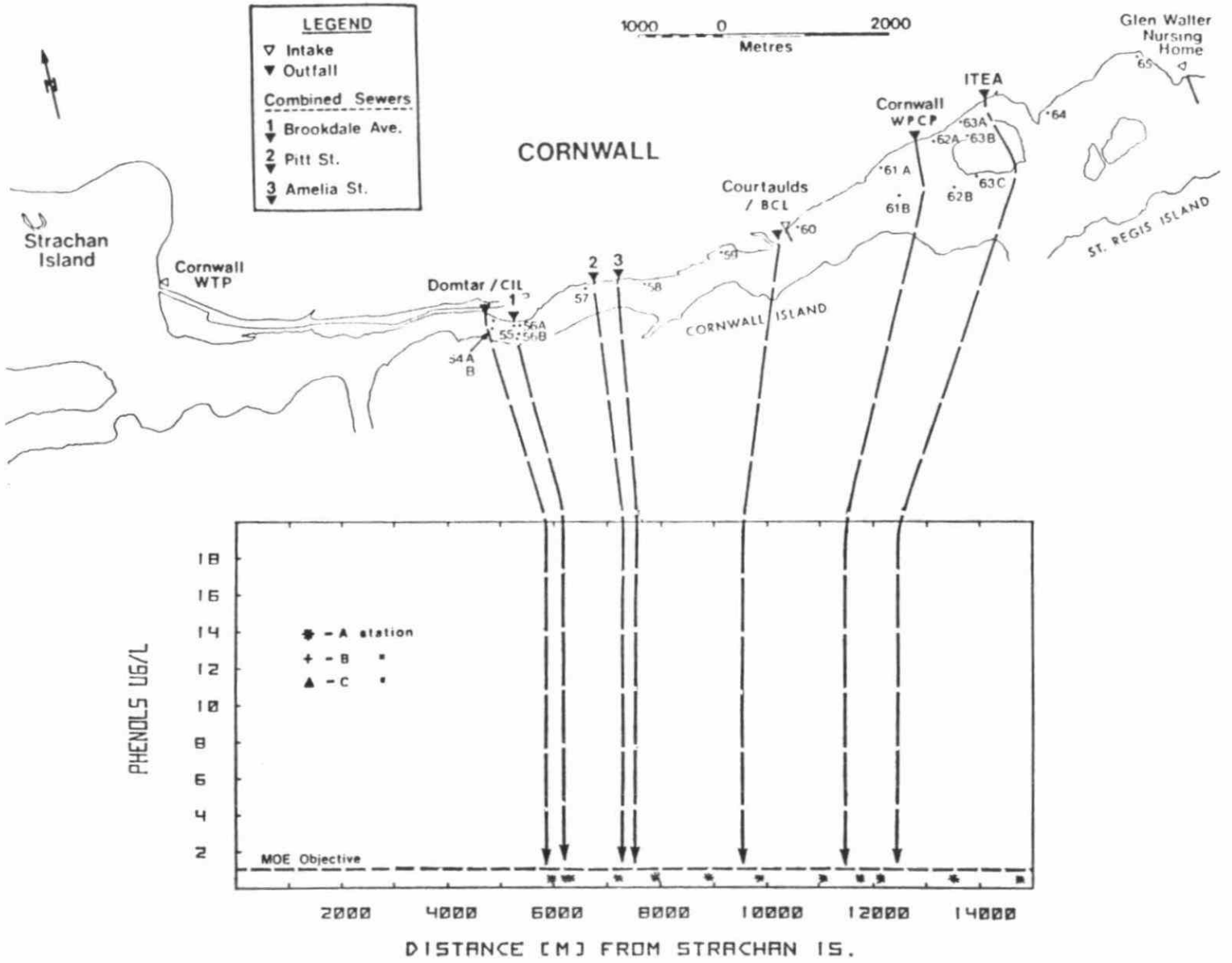

FIG 14. Mean Phenols Concentrations (µg/l) in St. Lawrence River surface waters (1.5 m. depth), June 24 – 26, 1980.

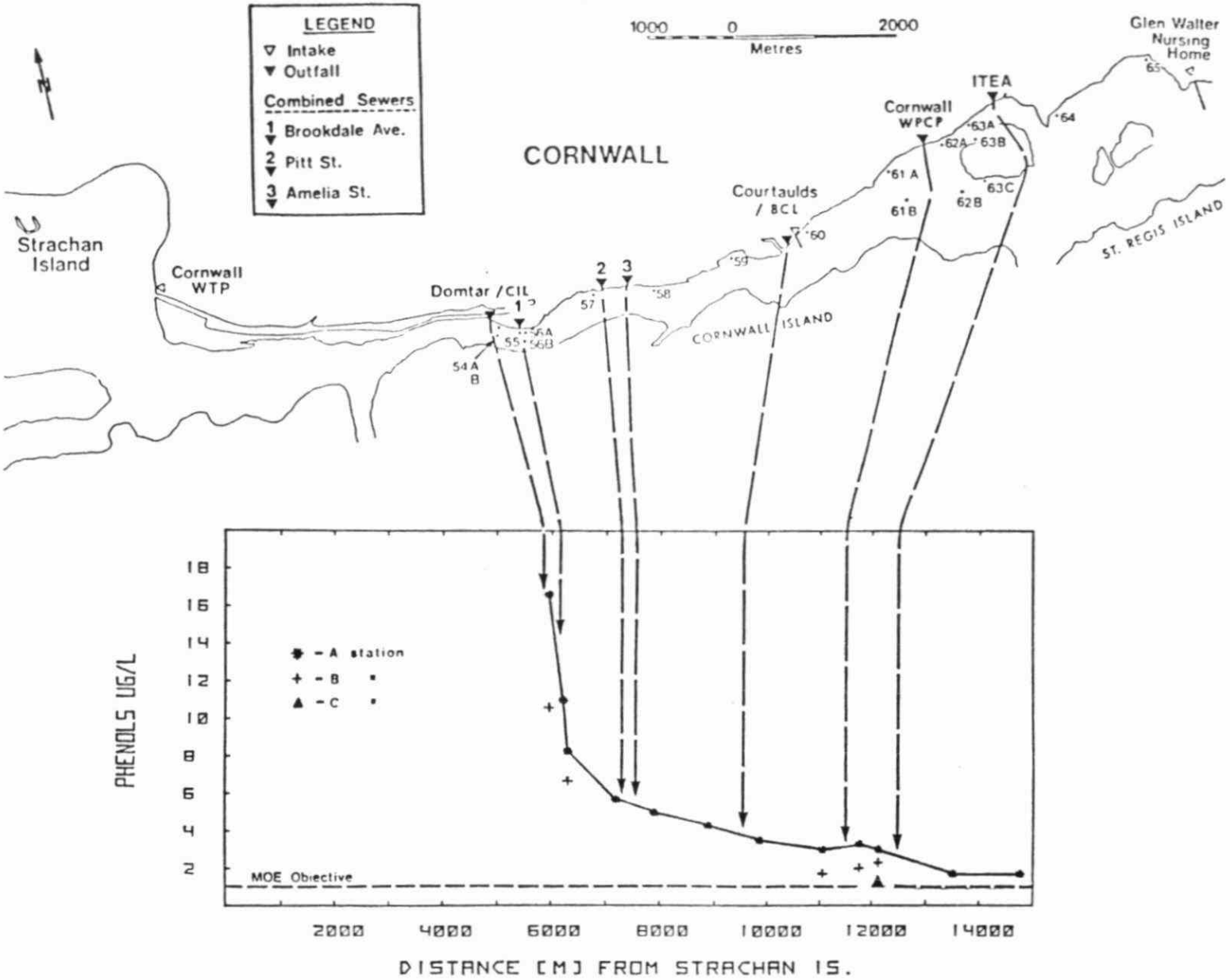

FIG 15. Mean Phenols Concentrations (µg/l) in St. Lawrence River surface waters (1.5 m. depth), July 29 - 31, 1980.

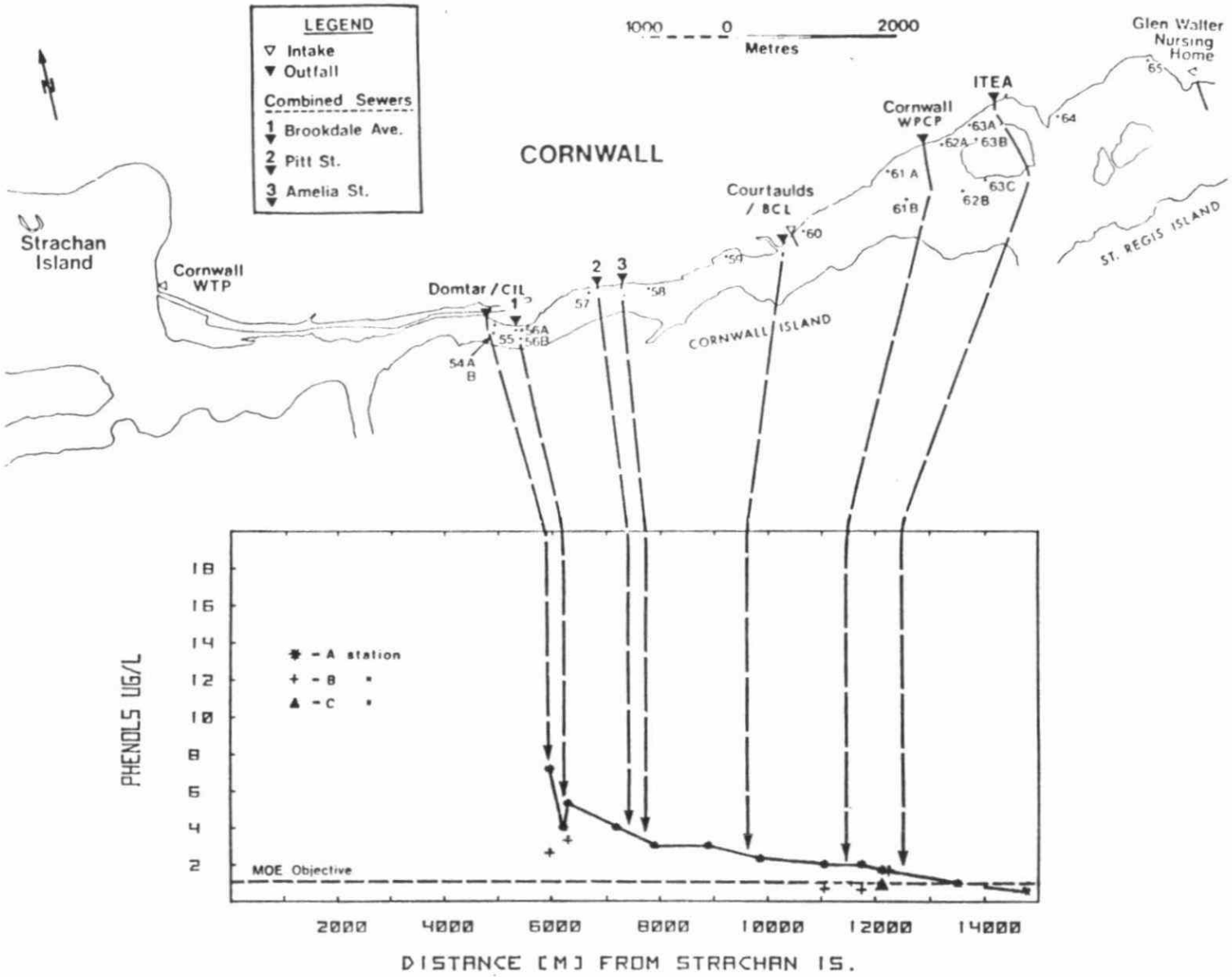

FIG 16. Mean Phenols Concentrations (µg/l) in St. Lawrence River surface waters (1.5 m. depth), Sept. 9 – 11, 1980.

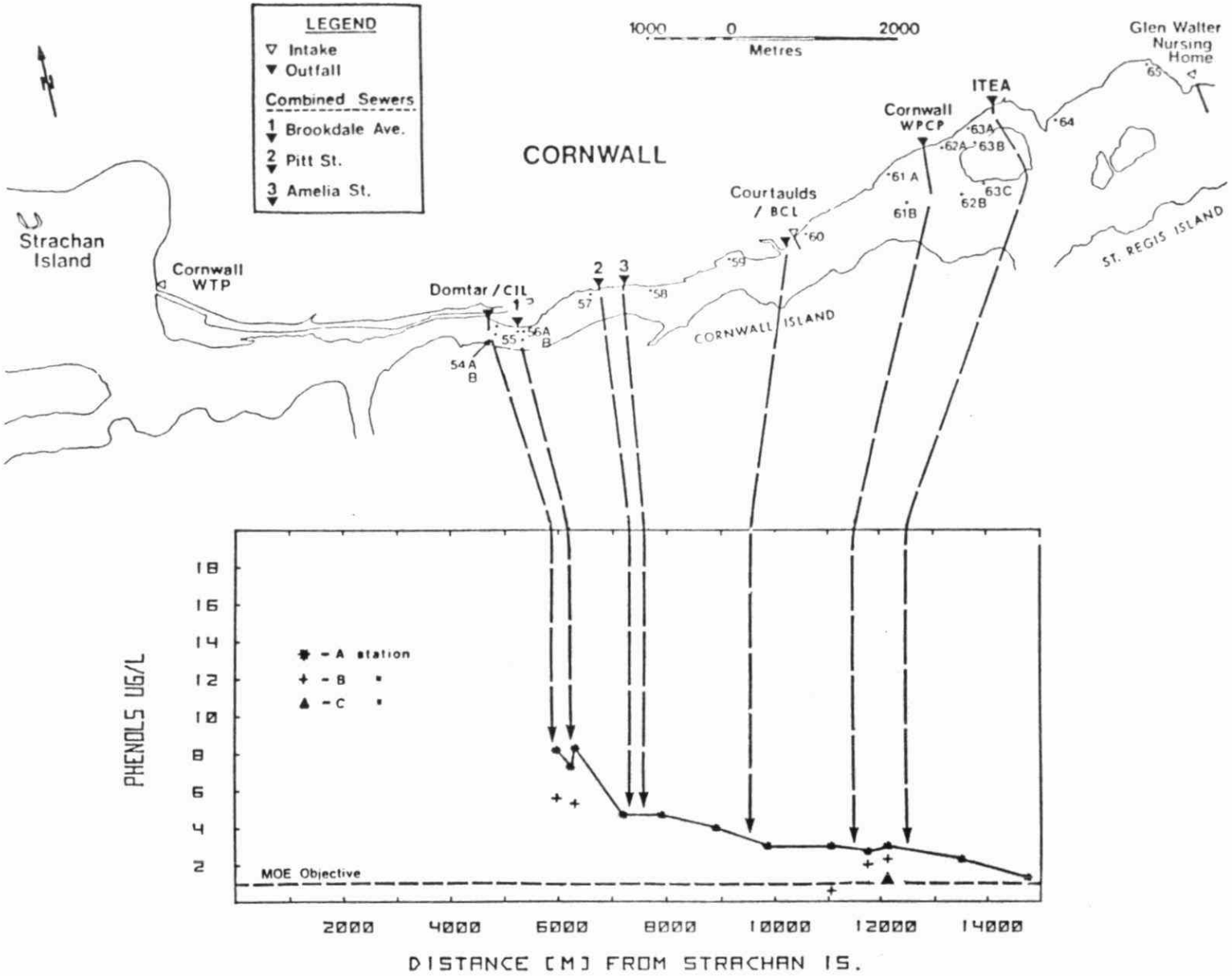

FIG 17. Mean Phenols Concentrations (µg/l) in St. Lawrence River surface waters (1.5 m. depth), Oct. 21 – 23, 1980.

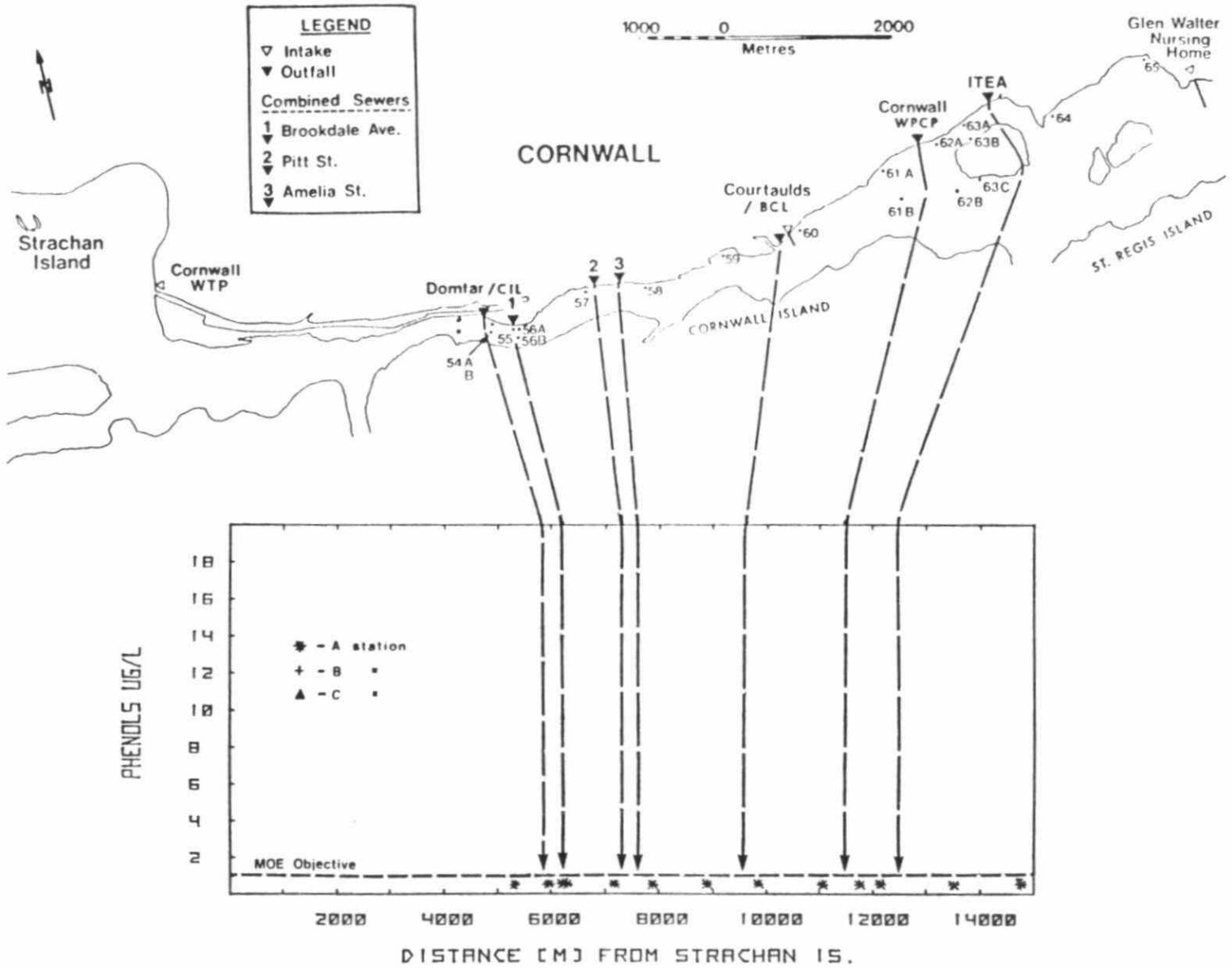

FIG 18. Mean Phenols Concentrations (µg/l) in St. Lawrence River surface waters (1.5 m. depth), Nov. 25 - 27, 1980.

For July, September and October, the months in which the surface water phenolic concentrations were in excess of the objective, the mean concentrations of phenolics in Domtar's effluent were 1533, 750 and 1667 ug/L, respectively (Table 8). These concentrations correspond to mean loadings of 216, 92 and 196 kg/d. Phenolics loadings from CIL/Cornwall Chemicals and the Cornwall WPCP during these surveys ranged from 0.004 to 0.032 kg/d and from 0.407 to 1.45 kg/d, respectively, levels which are significantly lower than those discharged by Domtar. The July 29, 1980 overflow event at the Brookdale Avenue combined sewer also contributed a small loading of phenolics (0.27 kg/d) to Cornwall waters.

Despite these exceedences of the phenolics objective in Ontario waters, no incidents of fish tainting or taste and odour problems in nearby water supplies were reported (R. Helliar, MOE Cornwall District Office, personal communication).

4.2.1.3.2 Polychlorinated Biphenyls and Organochlorine Pesticides

In 1979, PCBs were detected, on one occassion each, at the mouth of the Grasse River and in downstream waters adjacent to Reynolds Metals and the General Motors Foundry at levels above the PWQO of 0.001 ug/L for the protection of aquatic life (Table 9a and 9b). This low frequency of detection may partly be due to the method detection limit of 0.020 ug/L, which is higher than the PWQO. Although PCB loadings from the Grasse River to the St. Lawrence River were not quantified, their detection in downstream waters at up to 0.610 ug/L indicates that significant loadings of this contaminant occurred during the study period. The single detection of PCBs in Cornwall WTP raw water also suggests an upstream background level of this contaminant, since this water is drawn from Lake St. Lawrence.

More frequent sampling during 1980 showed that PCB concentrations at the Grasse River mouth (Table 9c) exceeded the PWQO in a minimum of 63% of the water samples examined. Detected values ranged from 0.020 to 0.070 ug/L. These values are similar to the range found in water samples collected during 1977 by Environment Canada (Chan, 1980). Using the mean annual flow listed earlier (section 1.1.1, pg. 12) the 1980 mean concentration of 0.023 ug/L would equate to a loading of

TABLE 8
PHENOLICS CONCENTRATIONS (ug/L) IN CORNWALL EFFLUENTS
SAMPLED DURING 1980 SURVEYS

Sampling		Domtar outfall	CIL outfall	Brookdale Ave. combined sewer	Cornwall STP effluent
June	24	100	2	-	7
	25	13	4	-	7
	26	<13	<9	-	<11
	x	42	5.0	-	8.3
	S.D.	50	3.6	-	2.3
July	29	1,600	16	8*	11
	30	1,200	4	-	6
	31	1,800	7	-	8
	x	1,533	9.0	-	8.3
	S.D.	306	6.2	-	2.5
September	9	850	9	-	11
	10	700	11	-	6
	11	700	1	-	9
	x	750	7.0	-	8.7
	S.D.	87	5.3	-	2.5
October	21	1,800	2	-	43
	22	1,700	2	-	30
	23	1,500	1	-	33
	x	1,667	1.7	-	35.3
	S.D.	153	0.6	-	6.8
November	25	-	<1	-	10
	26	-	2	-	13
	27	-	1	-	8
	x	-	1.2	-	10.3
	S.D.	-	0.8	-	2.5

x = Mean
S.D. = Standard Deviation
* = Only sampled during overflow event
"-" = No sample (or not calculated).
Note: Domtar shut down during November survey.

TABLE 9a.

PCBs AND ORGANOCHLORINE PESTICIDES CONCENTRATIONS (μg/L) IN RIVER WATER SAMPLES COLLECTED FROM THE NORTH SHORE OF THE ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	PCBs	Aldrin	Dieldrin	α-BHC	β-BHC	Lindane	α-Chlordane	γ-Chlordane	o,p-DDT	p,p-DDT	p,p-DDE	p,p-DDD	Endrin	Heptachlor	Heptachlor epoxide	HCB	Mirex	Thiodan I	Thiodan II
Cornwall																				
Stn. 112 (Control)	Oct. 2	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.002	X	X	X	X
Cornwall WTP	Sept. 21	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 25	X	X	X	X	X	.005	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 26	.090	X	X	X	X	X	X	X	X	X	.004	X	X	X	X	X	X	X	X
	Sept. 28	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.001	X	X	.004	X
Cornwall Canal	Sept. 25	X	X	X	.002	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 26	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 27	X	X	X	.008	X	.001	.001	X	X	X	.002	.005	X	X	.001	X	X	X	.003
Stn. 104 Courtaulds/ BCL	Oct. 10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.003	X	X	X	X
Stn. 094	Sept. 24	X	X	.001	.003	.001	.003	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 25	X	X	X	.001	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 26	X	X	X	.006	.001	.002	.005	X	.015	.005	X	.005	X	X	X	X	X	X	X
Stn. 095	Oct. 12	X	X	.001	X	X	X	X	X	X	X	X	X	X	X	.002	X	X	X	X
Stn. 071	Oct. 13	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Raisin R. Stn. 055	Sept. 27	X	X	X	.005	X	.001	.001	X	X	X	X	.020	X	X	X	X	X	X	X
Stn. 057	Sept. 27	X	X	X	.007	X	.002	X	X	X	X	X	.020	X	X	X	X	X	X	X
Detection Limit		.020	.001	.001	.001	.001	.001	.001	.001	.005	.005	.001	.005	.001	.001	.001	.001	.005	.001	.001
Water Quality Objectives:	GLWQA	-	.001		-	-	.010	.060		.003				.002	.001		-	ABSENT	-	
	PWQO	.001	.001		-	-	.010	.060		.003				.002	.001		-	.001	.003	

" - " indicates no sample or no analytical result.

X indicates not detected (ND)

TABLE 9b.

PCBs AND ORGANOCHLORINE PESTICIDES CONCENTRATIONS (µg/L) IN RIVER WATER SAMPLES COLLECTED FROM THE SOUTH SHORE OF THE ST. LAWRENCE RIVER DURING THE 1979 SURVEY

Sampling Location	Sampling Date	PCBs	Aldrin	Dieldrin	α-BHC	β-BHC	Lindane	α-Chlordane	γ-Chlordane	o,p DDT	p,p-DDT	p,p-DDE	p,p-DDD	Endrin	Heptachlor	Heptachlor epoxide	HCB	Mirex	Thiodan I	Thiodan II
Grasse River																				
Stn. 002	Sept. 20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 21	.150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 22	X	X	.002	.001	X	.001	.002	.002	X	X	X	X	X	X	X	X	X	X	X
	Sept. 23	X	X	X	.002	.001	.001	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 24	X	X	X	.001	X	.001	X	X	X	X	X	X	X	X	X	X	X	.003	X
	Sept. 25	X	X	X	.002	.001	.001	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 27	X	X	X	.004	X	X	X	X	X	X	X	X	X	X	.001	X	X	X	X
Stn. 033	Oct. 3	X	X	.003	X	X	X	X	X	X	X	X	X	X	X	.005	X	X	X	X
Reynolds Metals	Sept. 21	.610	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.002	X	X	X
	Sept. 25	X	X	X	.003	.001	.003	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
General Motors	Sept. 21	.510	X	.001	X	X	X	X	X	X	X	X	X	X	X	.001	.003	X	X	X
	Sept. 25	X	X	X	.001	X	.001	.002	.002	X	X	X	X	X	X	X	X	X	X	X
	Sept. 26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Raquette River																				
Stn. 003	Sept. 20	X	X	X	X	X	X	X	X	X	X	X	.030	X	X	X	X	X	X	X
	Sept. 21	X	X	X	.006	X	.001	X	X	X	X	X	X	X	X	.001	X	X	X	X
	Sept. 22	X	X	X	.001	X	X	X	X	X	X	X	.006	X	X	X	X	X	X	X
	Sept. 23	X	X	X	.002	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

TABLE 9b Continued

Sampling Location	Sampling Date	PCBs	Aldrin	Dieldrin	α-BHC	β-BHC	Lindane	α-Chlordane	γ-Chlordane	o,p DDT	p,p-DDT	p,p-DDE	p,p-DDD	Endrin	Heptachlor	Heptachlor epoxide	HCB	Mirex	Thiodan I	Thiodan II
Raquette River Stn. 003 (Continued)	Sept. 24	X	X	X	.002	X	X	X	X	X	X	X	X	.001	X	X	X	X	.002	X
	Sept. 25	X	X	X	.002	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 27	X	X	X	.001	X	X	X	X	X	X	X	X	X	X	.001	X	X	X	X
	Oct. 4	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.002	X	X	X	.001
St. Regis River Stn. 068	Sept. 20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 21	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 22	X	X	X	.003	X	.002	X	X	X	X	X	X	X	X	X	X	X	.003	X
	Sept. 23	X	X	X	.001	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 24	X	X	X	.001	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 25	X	X	X	.001	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Sept. 27	X	X	X	.008	X	X	X	X	X	X	X	X	X	X	.001	X	X	X	X
	Oct. 5	X	X	X	X	X	X	X	X	X	X	X	X	X	X	.003	X	X	X	X
Salmon River Stn. 060	Sept. 26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Detection Limit		.020	.001	.001	.001	.001	.001	.001	.001	.005	.005	.001	.005	.001	.001	.001	.001	.005	.001	.001
Water Quality Objectives:	GLWQA	-	.001		-	-	.010	.060		.003				.002	.001		-	ABSENT	-	
	PWQO	.001	.001		-	-	.010	.060		.003				.002	.001		-	.001	.003	

" - " - indicates no sample or no analytical result.
X - indicates not detected (ND)

TABLE 9C

PCBs AND ORGANOCHLORINE PESTICIDES CONCENTRATIONS (ug/L)

IN GRASSE RIVER MOUTH WATER SAMPLES DURING 1980 SURVEYS

Sample Date	Parameter							
	PCBs	Dieldrin	α-BHC	β-BHC	Lindane (γ-BHC)	Heptachlor Epoxide	HCB	Thiodan II
June 24	0.030	0.005	0.004	0.003	0.005	ND	ND	ND
25	-	-	-	-	-	-	-	-
26	ND	ND	0.002	0.004	0.002	0.001	ND	ND
July 29	0.030	ND	0.005	0.001	0.005	ND	0.001	ND
30	-	-	-	-	-	-	-	-
31	ND	ND	ND	ND	ND	ND	ND	ND
September 9	0.020	ND	0.005	0.001	0.001	ND	ND	0.005
10	-	-	-	-	-	-	-	-
11	0.070	ND	ND	ND	ND	ND	ND	ND
October 21	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-
23	-	-	-	-	-	-	-	-
November 25	ND	ND	0.001	ND	ND	ND	0.006	ND
26	-	-	-	-	-	-	-	-
27	0.030	ND	0.001	ND	ND	ND	0.001	ND
Detection Limit	0.020	0.001	0.001	0.001	0.001	0.001	0.001	0.001
% of samples ≥ Det'n Limit	63	13	75	50	50	13	38	13
GLWQA/PWQO** Objectives	0.001**	0.001	-	-	0.010	0.001	-	0.003**
% of Samples > Objective	63	13	-	-	0	0	-	13

ND = Not detected (below method detection limit).

\- = Not sampled.

Note: (1) Aldrin, α-Chlordane, γ-Chlordane, o,p-DDT, p,p'-DDT, p,p-DDD, p,p-DDE, Endrin, Heptachlor, Thiodan I and Mirex were not detected in any of the above water samples.

about 62 g PCBs/d from the Grasse River. This is similar to that calculated for all Ontario point sources monitored in 1979 (section 4.1.2.2, pg. 32), but much lower than the loading rate from the ALCOA facility in 1980 (176 to 281 g/d, using flow rate and effluent concentration data in IJC, 1982). This difference may be due to: i) physical losses of discharged PCBs to Grasse River sediments (adsorption) and hence lower water column concentrations or ii) significant daily deviations in the Grasse River flow from the annual mean, necessitating the use of daily flows for loading calculations.

During 1979, organochlorine pesticides, namely dieldrin, pp-DDD, o,p-DDT, p,p-DDT and Thiodan I were detected, on at least one occasion, in the vicinity of all of the major tributaries, in the Cornwall Canal, and near Reynolds Metals, General Motors and Courtaulds/BCL discharges at levels in excess of PWQO and GLWQA objectives (Tables 9a and 9b). Diedrin, α, β and γ-BHC, heptachlor epoxide and Thiodan II were also occasionally detected during 1980 sampling of the Grasse River mouth (Table 9c). Of these, BHC isomers were present in 50% to 75% of the samples, but at levels below available objectives. However, dieldrin and Thiodan II exceeded their respective objectives in 13% of samples.

PCBs, p,p-DDE, heptachlor epoxide and Thiodan I were also detected, each on one occasion above PWQO and GLWQA objectives, in raw water from the Cornwall WTP located upstream of Cornwall-Massena. Heptachlor epoxide was also detected once above its objective at the upstream control station (Stn. 112).

Endrin; α, β and γ - BHC; α and γ - chlordane and HCB, although detected on occasion, were present in concentrations below their respective GLWQA or PWQO objectives, where available.

4.2.2 Mixing Zone Simulations

A multiple-source mathematical model, developed by the University of Windsor, was applied to predict the mixing zone associated with the multiple sources located along the Cornwall shore. The model indicated that discharges from the Domtar/CIL/Cornwall Chemicals and the

Courtaulds/BCL diffusers would be confined mainly to the north shore. On the other hand, the model predicted that discharges from the Cornwall WPCP would flow mainly south of Pilon Island and then combine with river discharges from the U.S. shoreline further downstream.

The confinement of the Domtar and Courtaulds/BCL discharges to the north shore is attributed mainly to the strong lateral river velocity, (see Appendix Table XVIII and Figure I), as well as to the proximity of the Domtar/CIL/Cornwall Chemicals outfall diffuser ports to the shore. Forty percent of these diffuser ports are located close to shore in shallow water, 0.8 m (2.5 ft.) or less, and thus the diffuser does not produce efficient mixing with the river water. Using loading data from the 1979 survey, the mixing zone for phenolic compounds (i.e. the area with concentrations > 1 ug/L), which are discharged mainly from Domtar, was predicted to extend about 10 km down river with a maximum lateral width of up to 190 meters (Figure 19). Model predictions coincided quite well with actual results observed during subsequent 1980 field studies (see Figures 15, 16 and 17).

4.2.3 Suspended Sediments

The 1979 survey yielded information on concentrations of PCBs, ether solubles (oils and greases) and heavy metals associated with suspended sediments at a number of stations in the St. Lawrence River (Table 10). Station locations are shown in Figure 2. Concentrations of PCBs and metals in unfiltered water samples collected simultaneously at the same stations are listed in Table 11.

The highest concentrations of suspended sediments-associated chromium, lead, mercury, zinc and PCBs along the north shore were found at station 095, near the Courtaulds/BCL outfalls. Aluminum and copper levels at this station were identical to those at station 104, located downstream of the Domtar/CIL/Cornwall Chemicals diffuser outfall. Lower concentrations of these parameters were found at Farlinger's Point (station 071), about 3.5 km downstream. Suspended sediments-associated aluminum and iron concentrations were highest at the mouth of the Raisin River (station 055).

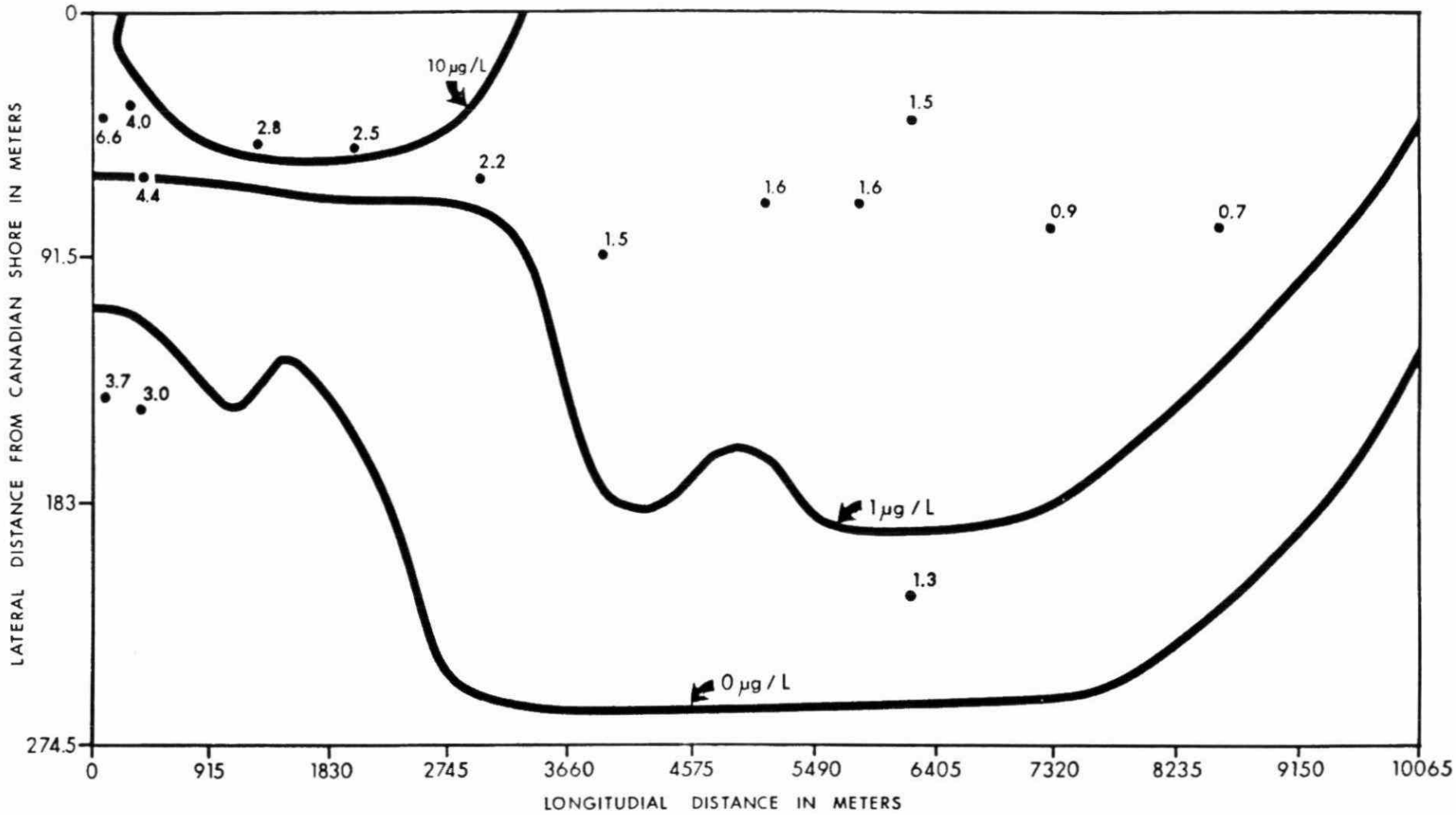

FIG. 19 Predicted Phenol concentration contours in the St. Lawrence River at Cornwall from Domtar's outfall to 10km downriver, based on 1979 Domtar loading data. 1980 station survey means are ploted for comparison.

TABLE 10

CONCENTRATION OF METALS*, PCBs AND ETHER SOLUBLES (ug/g)**

IN SUSPENDED SEDIMENTS FROM THE ST. LAWRENCE RIVER (1979)

	STATION							
	112	104	095	071	055	033	003	068
Aluminum	-	17000	17000	15000	26000	22000	17000	12000
Cadmium	-	0.35	1.2	1.5	<1.5	0.6	2.0	1.8
Chromium	-	56	110	49	61	60	55	43
Copper	-	140	140	130	88	65	220	62
Iron	-	23000	22000	21000	34000	33000	34000	36000
Lead	-	62	100	84	70	34	90	63
Mercury	0.86	0.66	2.4	0.69	0.14	0.19	0.47	0.32
Zinc	-	210	550	410	200	150	370	300
PCBs	ND	0.076	0.235	0.037	-	0.660	0.035	0.130
Ether solubles	33,000	5,666	-	10,250	5,000	4,220	9,000	2,100

* = Metals are "total".

** = Dry Weight Basis.

"-" = No Data Available (insufficient material for analysis).

ND = Not Detected (detection limit = 0.01 ug/g)

TABLE 11

CONCENTRATION OF METALS* AND PCBs (ug/L) AND
SUSPENDED SEDIMENTS (mg/L) IN WATER SAMPLES
COLLECTED DURING CENTRIFUGATION (1979)

	STATION							
	112	104	095	071	055	033	003	068
Aluminum	60	-		-	80	280	70	140
Cadmium	6	-	-	-	<5	8	7	8
Chromium	<20	-	-	-	<20	<20	<20	<20
Copper	<10	-	-	-	<10	20	<10	<10
Iron	50	-	-	-	80	360	360	540
Lead	<30	-	-	-	<30	<30	<30	<30
Mercury	0.15	-	-	-	0.04	0.32	0.04	0.04
Zinc	<10	-	-	-	<10	40	20	20
PCBs	ND	ND	ND	ND	ND	ND	ND	ND
Suspended solids	4	2	2	2	3	10	1	7

* = Values for metals are total (unfiltered water samples).

ND = Not detected (detection limit = 0.010 ug/L).

"-" = No data available.

Along the south shore, concentrations of aluminum, chromium and PCBs associated with suspended sediments were highest at the confluence of the Grasse and St. Lawrence Rivers (station 033). The highest concentrations of suspended sediments-associated cadmium, copper, lead, mercury, zinc and ether solubles were found at the mouth of the Raquette River (station 003).

Unfortunately, due to the small sample size, only a few analytical results were available for suspended solids quality at the upstream control (station 112). However, these clearly indicated the influence of PCB sources in the Cornwall and Massena areas and of mercury in Cornwall. In contrast, the presence of mercury and high ether solubles levels at the control station indicates an additional upstream background influence for these parameters (Table 10).

The $\log_{10}$ of the ratio between contaminants concentrations in suspended sediments and the associated aqueous phase (partition coefficient) is presented in Table 12. The significance of this ratio lies in the fact that it allows an assessment of which phase (particulate or aqueous) a particular contaminant has a greater affinity for. The formula utilized in calculation of these values was:

$$\text{Partition coefficient (P)} = \log_{10} \frac{Css}{Cw - Css}$$

Where: Css = Concentration of contaminant in suspended solids normalized to concentration in an equivalent weight of water (i.e. multiplied by suspended solids concentration).

Cw = Concentration of contaminant in associated water.

TABLE 12

CALCULATED PARTITION COEFFICIENTS (log_{10} P) FOR
TRACE CONTAMINANTS IN THE ST. LAWRENCE RIVER (1979)

	STATION				
	112	055	033	003	068
Aluminum	--	7.1	5.6	5.5	5.3
Cadmium	--	<2.5	1.8	2.5	2.4
Chromium	--	<3.5	<3.5	<3.4	<3.3
Copper	--	<3.9	3.5	<4.4	3.8
Iron	--	--*	6.0	5.0	5.1
Lead	--	<3.4	<3.1	<3.5	<3.3
Mercury	3.8	3.5	2.8	4.1	3.9
Zinc	--	<4.3	3.6	4.3	4.2
PCBs, total	--	--	<5.3	<3.5	<4.2

"--" = No data available or value could not be calculated due to higher concentration in aqueous than in particulate phase*.

< = Actual value is less than indicated, since none was detected in water sample (detection limit used for calculation).

Limitations due to detection limits for some metals as well as PCBs in conventional (1 L) samples precluded calculation of accurate values for each contaminant. Also, corresponding total water data was not available for all stations (Table 11). Nevertheless, as reflected by the $\log_{10}$ P values (range: 1.8 to 6.0) for cadmium, copper, mercury and zinc, these metals have a tendency to adsorb onto particulate matter. Although aluminum and iron both had very high $\log_{10}$ P values, this mainly reflects particle chemistry, since these elements comprise major portions of clay minerals (Buckman and Brady, 1969), and fine-grained inorganics (clay) material and organic matter would be expected to be the major constituents of suspended sediments. Similar ranges in $\log_{10}$ P values were observed for chromium, lead and PCBs (<3.1 to <5.3). Due to the assumptions made in their calculation (see footnote, Table 12), these are probably conservative approximations and should be used with caution. Also, because of variable states of equilibrium from station to station, partition coefficients may be expected to vary considerably. Nevertheless, it is noteworthy that the average of the range calculated for total PCBs ($\sim$4.9) is identical to that determined by Kuntz and Warry (1983), using a more extensive data base for the outlet of the Niagara River.

An approximation of the contribution of dissolved contaminants to the total in a sample was obtained by subtracting concentrations in suspended sediments (normalized to an equivalent mass of water) from those in total (unfiltered) water samples. As shown by Table 13, the relative importance of the particulate forms generally decreases in the sequence:

Fe > Al > PCBs > Zn, Cu > Cr, Pb, Hg > Cd

This ordering is somewhat similar to the findings of Yeats and Bewers (1982) for particulate-associated metals in the St. Lawrence River near Quebec City. Also in concurrence with their findings, is our observation that only the particulate forms of aluminum and iron were an important fraction of the total water concentrations (see Table 13); the influence of suspended sediment contributions is minor for cadmium, chromium, copper, lead, mercury, zinc and PCBs. Therefore, although concentrations on particles may be lower during periods of high suspended sediment concentration (Bradley and Lewin, 1982; McCrea et al., 1985), the proportion of contaminant load carried by the

TABLE 13
CONCENTRATION OF METALS AND PCBs (ug/L) IN WATER AND
PARTICULATE (SUSPENDED SEDIMENTS) FRACTION IN THE
ST. LAWRENCE RIVER (1979)

FRACTION	STATION	Al	Cd	Cr	Cu	Fe	Pb	Hg	Zn	PCBs
Total	112	60	6	<20	<10	50	<30	0.15	<10	ND
	055	80	<5	<20	<10	80	<30	0.04	<10	ND
	033	280	8	<20	20	360	<30	0.32	40	ND
	003	70	7	<20	<10	360	<30	0.04	20	ND
	068	140	8	<20	<10	540	<30	0.04	20	ND
Particulate	112	-	-	-	-	-	-	0.00344	-	ND
	055	78	<0.0045	0.183	0.264	102	0.210	0.00042	0.60	-
	033	220	0.0060	0.600	0.650	330	0.340	0.00190	1.50	0.00660
	003	17	0.0020	0.055	0.220	34	0.090	0.00047	0.37	0.000035
	068	84	0.0126	0.301	0.434	252	0.441	0.00224	2.10	0.00091
Dissolved	112	-	-	-	-	-	-	98	-	-
as % of	055	3	≈99	>99	>97	?	>99	99	>94	-
Total	033	21	99	<97	97	8	>99	99	96	≳34
	003	76	99	>99	>98	90	>99	99	98	≳99
	068	40	99	>98	>95	53	>93	95	90	≳91

particulate phase is clearly related to the suspended load. In the St. Lawrence River, where suspended sediment levels are relatively low (1-10 mg/L, this study; 10 mg/L, Yeats and Bewers, 1982), the major load of many contaminants may be carried by the dissolved (aqueous) phase. Indeed, more recent (1981) sampling in the Cornwall area has shown that, with the exception of gamma-chlordane, p,p'-DDE and mirex, the major fraction (79% to 100%) of the total concentrations of organochlorine pesticides and PCBs was in the aqueous phase (McCrea et al, 1985). Furthermore, they observed that the detected pesticides were present at sub-ppt levels in water samples, while PCBs were found at about 2 ppt (0.002 ug/L). Therfore, while the present database for river samples was inadequate to calculate a total contaminants load for this section of the St. Lawrence River, or to determine the spatial distribution of a number of contaminants in water, future studies with these objectives require sampling of water with adequate frequency and detection limits.

4.2.4 Bottom Sediment Characteristics and Quality

In 1979, surficial sediment samples were obtained at all but 7 of the 64 stations shown in Figure 3. Lack of sample was due to the lack of bed material, rapid current or a combination of both factors at these stations (see also Appendix, Table XVI).

Particle size and organic content have an important influence on the concentration of the more hydrophobic inorganics and organic contaminants in sediments (Forstner and Whittmann, 1983; Choi and Chen, 1976). For example, the large surface area of suspended sediments allows relatively large amounts of contaminants to adsorb to particulate surfaces. These particulates will ultimately settle out and become part of the bottom sediments when vertical "gravitational" forces exceed horizontal "river" forces in slower-flowing areas of a river.

4.2.4.1 Physical Characteristics

The spatial distribution of mean particle size (expressed in phi units)* of surficial sediments (top 3 cm) is shown in Figure 20. These were calculated from the detailed grain size analyses found in the Appendix, Table XIII, using a G statistics program.

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phi = $-\log_2$ (mean particle size in mm)

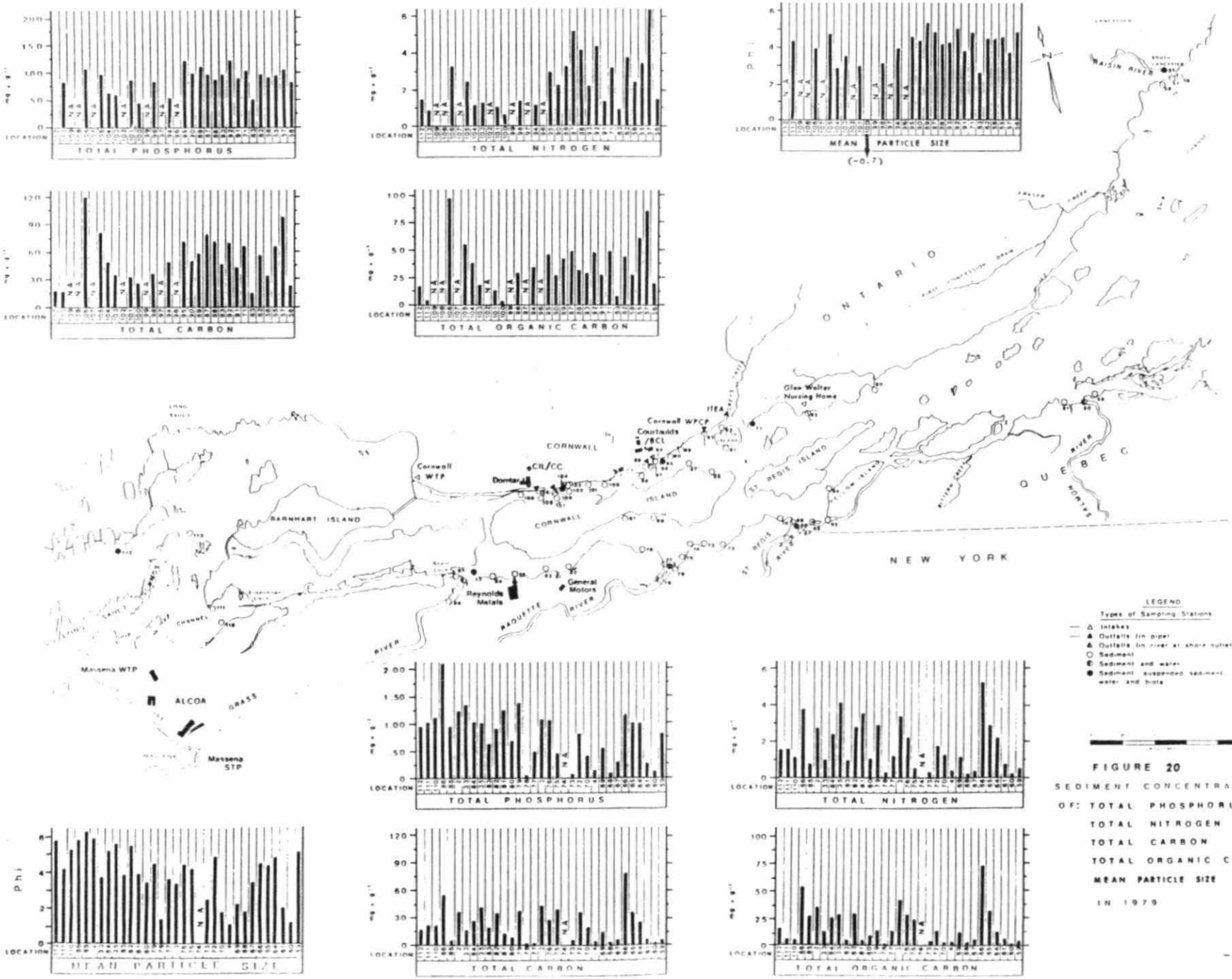


FIGURE 20

SEDIMENT CONCENTRATIONS OF: TOTAL PHOSPHORUS
TOTAL NITROGEN
TOTAL CARBON
TOTAL ORGANIC CARBON
MEAN PARTICLE SIZE
IN 1979

The fast flow of the St. Lawrence River along the north shore and the resultant particle sorting is evident from the high proportion of gravel downriver from the Domtar/CIL/Cornwall Chemicals diffuser outfall, where up to 60% gravel and 19% very coarse sand were found at station 100. Farther downstream, a widening and deepening of the channel results in a decrease in current velocity along the north shore. This results in the deposition not only of gravel and sand but also of the finer particulates and an attendant increase in mean particle size (Figure 20). For example, at stations 095, 090 and 089, in the vicinity of Courtaulds/BCL, silt comprised 52%, 45% and 80%, respectively, of the sediment samples.

High silt content was also characteristic of bottom sediment samples collected in and near the mouths of tributaries to this section of the St. Lawrence River. For example, the silt content in the vicinity of the Raisin River ranged from 37% to 68%. Sediment from and downstream of the Grasse River mouth (stations 002, 003, 084) also had a high silt content, ranging from 35% to 72%. At the Reynolds Metals Co. outfall, silt content was 73%. Downriver, along the U.S. shore, the mean particle size increased slightly (Figure 20).

Sediments at and immediately downstream of the Raquette River mouth (stations 077, 003, 076, 075) were variable, composed of from 8% to 39% silt. Mean particle size increased at the confluence of the Raquette and St. Lawrence Rivers (Figure 20). Sediments from the mouth of the Salmon River were predominantly coarse and medium sand.

4.2.4.2 Sediment Chemistry

This section describes the distribution of organic and inorganic contaminants and nutrients in the river and delineates areas of sediment impairment. Concentrations of contaminants in the sediments were compared to levels at the stations upstream of Cornwall and Massena (112, 113, 111 and 110), since these had relatively low levels in their sediments; to 1979 source loadings data; and to available Provincial guidelines for the disposal of dredged material in open water (Persaud and Wilkins, 1976). These guidelines, as well as the mean, range and percent of stations with concentrations exceeding the respective guidelines, are summarized in Table 14 for the upstream stations and for the north and south shores.

TABLE 14
SUMMARY OF SEDIMENT CHEMISTRY DATA FOR THE ST. LAWRENCE RIVER, 1979

PARAMETER	Provincial Dredging Guideline*	Upstream Stations				North Shore				South Shore			
		Mean	S.D.	Range	% > Guideline	Mean	S.D.	Range	% > Guideline	Mean	S.D.	Range	% > Guideline
Total Phosphorus (mg/g)	1.00	0.95	0.13	0.80-1.10	25	0.89	0.21	0.50-1.20	22	0.76	0.46	0.15-2.10	28
TKN	2.00	1.15	0.48	0.48-1.50	0	2.49	1.46	0.50-6.10	61	1.73	1.39	0.15-5.30	41
Total Carbon	-	18.5	2.9	16-21	-	55	25	14-120	-	25	19	1.1-77	-
TOC	-	9.2	5.0	4.0-16	-	35	24	<0.1-97	-	18	18	0.2-73	-
Ether Solubles (ug/g) (Oils & Greases)	1500	249	72	183-319	0	2603	3264	191-13838	39	938	877	27-3100	16
Aluminum (ug/g)	-	11075	4044	6300-16000	-	9600	3827	4200-16000	-	10069	7206	1600-24000	-
Cadmium	1.0	0.29	0.16	<0.30-0.45	0	0.93	1.13	1.20-5.70	22	0.66	0.51	<0.40-2.10	14
Chromium	50	24	7	14-29	0	34	14	13-59	9	22	15	<3-56	3
Copper	25	15	4.9	9.8-20	0	56	103	7.5-530	61	22	23	<2-110	31
Iron	10000	17500	4041	12000-21000	100	14217	4396	7300-23000	83	16103	8917	4100-35000	66
Lead	50	10	2.9	5.5-12	0	118	330	16-1600	26	18	14	<3-53	3
Mercury	0.3	0.09	0.03	0.06-0.12	0	2.82	5.25	0.03-19.8	65	0.10	0.09	<0.01-0.36	3
Zinc	100	59	16	36-71	0	454	874	25-4100	65	92	65	16-250	41
PCBs, Total (ng/g)	50	41	72	ND-150	25	221	598	ND-2670	61	348	501	ND-1980	64
Aldrin	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-
Dieldrin	-	ND	-	ND	-	2	2	ND-10	-	1	5	ND-25	-
Alpha-BHC	-	4	4	ND-8	-	2	2	ND-5	-	1	2	ND-10	-
beta-BHC	-	1	2	ND-4	-	8	10	ND-37	-	3	6	ND-29	-
gamma-BHC (Lindane)	-	2	3	ND-7	-	3	3	ND-9	-	12	18	ND-62	-
alpha-Chlordane	-	4	6	ND-13	-	4	4	ND-18	-	14	30	ND-120	-
gamma-Chlordane	-	4	5	ND-11	-	2	2	ND-6.7	-	0.9	1	ND-2	-
o,p - DDT	-	11	16	ND-35	-	3	1	ND-5	-	7	13	ND-64	-
p,p' - DDT	-	21	37	ND-77	-	3	2	ND-10	-	13	25	ND-120	-
p,p' - DDD	-	14	22	ND-47	-	3	1	ND-5	-	26	57	ND-190	-
p,p' - DDE	-	1	1	ND-3	-	14	48	ND-210	-	11	15	ND-52	-
Endrin	-	ND	-	ND	-	0.6	0.6	ND-3	-	4	17	ND-89	-
Heptachlor	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-
Heptachlor epoxide	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-
Hexachlorobenzene	-	ND	-	ND	-	11	21	ND-87	-	2	3	ND-13	-
Mirex	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-
Thiodan I	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-
Thiodan II	-	ND	-	ND	-	ND	-	ND	-	ND	-	ND	-

TKN - Total Kjeldahl Nitrogen
TOC - Total Organic Carbon
S.D.- Standard Deviation

ND - Not Detected
"-" - Not Available

The results (Figures 20-27) indicate high concentrations of various contaminants in sediments downstream of the mouths of the tributaries to the study area. However, samples taken adjacent to, or in the immediate vicinity of, some outfalls indicated little direct evidence of discharge of the contaminants in question. The probable explanation for this situation is that suspended particulates and associated contaminants introduced to fast-flowing portions of the St. Lawrence River via effluents settle out in quiescent reaches downstream of source areas such as in embayments and river mouths. These are the zones of low energy, or depositional areas (Folk and Ward, 1957; Thomas et al., 1972).

4.2.4.2.1 **Nutrients**

Phosphorus: Concentrations of total phosphorus in sediments along the north shore ranged from 0.50 to 1.20 mg/g, with the highest levels occurring downstream of major sources (e.g. Domtar, Cornwall WPCP) as well as in areas of sediment deposition (e.g. vicinity of Courtaulds/BCL complex, mouth of Raisin River) (Figure 20). Concentrations in excess of the Provincial dredging guideline of 1.00 mg/g were found in 22% of the samples.

Along the south shore, concentrations of total phosphorus exceeded the dredging guideline in 28% of sediment samples. Concentrations ranged from 0.15 to 2.10 mg/g, the highest levels being associated with tributaries (e.g. Grasse, Raquette and St. Regis Rivers).

Nitrogen: Total Kjeldahl nitrogen (TKN) distribution in sediments was somewhat similar to that of phosphorus (Figure 20). Along the north shore, the highest concentrations were found downstream of the major sources of nitrogen in 1979 (e.g. Domtar and Cornwall WPCP), and in areas of sediment deposition (e.g. vicinity of Courtaulds/BCL, mouth of Raisin River) and heavy macrophyte growth (Owen and Wile, 1975). Although the Cornwall WPCP was the largest single source (Table 3a), an immediate downstream increase in sediment nitrogen levels was not observed. Concentrations ranged from 0.50 to 6.1 mg/g, with 61% of stations having TKN sediment levels in excess of the Provincial guideline of 2.00 mg/g.

Concentrations of TKN along the south shore ranged from 0.15 to 5.3 mg/g, with the highest levels occurring at the mouths of the three major tributaries. 41% of samples had concentrations above the dredging guideline.

Carbon: Distribution patterns of total organic carbon (TOC) and total carbon (TC) were virtually identical in sediments (Figure 20), and like phosphorus and nitrogen, reflected inputs from municipal and industrial facilities in Cornwall as well as areas of fine-grained sediment deposition and heavy macraphyte growth. Concentrations of carbon were highly variable in sediments. Concentrations of TC and TOC ranged from 14 to 120 mg/g and <0.1 to 97 mg/g, respectively, along the north shore, with <0.4% to 94% being organic carbon. Along the south shore, TC ranged from 1.1 to 77 mg/g, TOC from 0.2 to 73 mg/g and percent organic carbon ranging from 10% to 100%.

4.2.4.2.2 Organochlorine Pesticides and PCBs

Aldrin and Dieldrin: Aldrin and dieldrin are primarily used to control soil insects (including termites around buildings) and hence may reach water courses via agricultural or urban runoff. In Ontario, use is regulated by permit (MOE, 1982a). Aldrin was not identified in any water, sediment or effluent samples collected. However, dieldrin, was detected in a few sediment samples. This may be due to the relatively rapid metabolic conversion of aldrin to dieldrin by some organisms (Gakstatter, 1968; Casarett and Doull, 1975) in addition to actual dieldrin use and inputs. As shown by Figure 21, the only (as well as the highest) detectable concentration along the south shore (25 ug/kg), was found at station 035, near the Reynolds Metals Co. outfall. This is probably related to the settling out of contaminated suspended sediments from upstream sources, such as the Grasse River watershed, and not to industrial discharges of dieldrin. This conclusion is based on three pieces of evidence. First , dieldrin was not found in the water near the outfall of Reynolds Metals Co. Second, of eight water samples collected in the vicinity of the Grasse River mouth, two contained dieldrin in excess of the Agreement and Provincial water quality objective of 0.001 ug/L (see Table 9b). Third, mean sediment particle size was finest at station 035 (Figure 20), near the Reynolds Metals Co. outfall, suggesting that this is a depositional area.

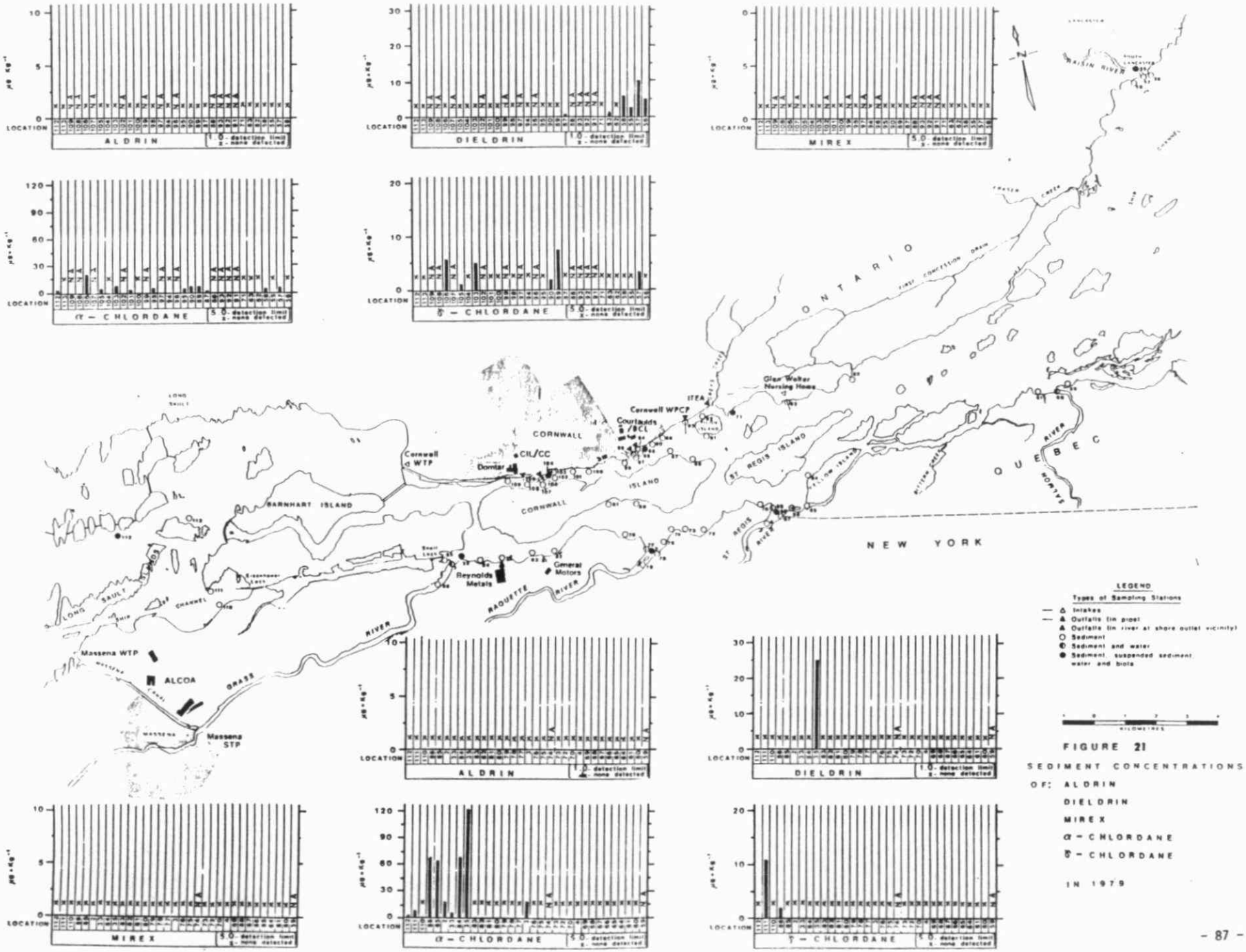


FIGURE 21

SEDIMENT CONCENTRATIONS OF: ALDRIN
DIELDRIN
MIREX
α – CHLORDANE
γ – CHLORDANE

IN 1979

The largely rural nature of the land drained by the Raisin River may also explain the presence of dieldrin in bottom sediments (2 to 10 ug/kg) sampled at the mouth of this river. Other stations sampled along the north shore were for the most part situated in close proximity to Cornwall and dieldrin was not detected in the bottom sediments there (Figure 21), although small loadings were detected in some of the effluents sampled (Table 3c).

Alpha (α) - and Gamma (γ) - Chlordane: In Ontario, chlordane is used for the control of termites and soil insect pests (e.g. on agricultural crops, lawns). Samples from twelve of twenty-one stations along the north shore contained detectable concentrations (3 to 18 ug/kg) of alpha-chlordane (Figure 21). The highest concentration was found at station 106, downstream of the CIL/Domtar/Cornwall Chemicals combined diffuser. The Domtar effluent contained low levels of alpha- and gamma-chlordane and Domtar and the Cornwall WPCP were the only identified sources in 1979 (Table 3c). Gamma-chlordane was found in the sediments along the north shore (1 to 7 ug/kg), near the outfalls of Domtar/CIL/Cornwall Chemicals and Courtaulds/BCL and at the Raisin River. In the case of the latter, this suggests local or agricultural uses.

Along the south shore, alpha-chlordane was found in the sediments associated with the Grasse River, with the highest concentration (120 ug/kg) being found at station 035 near the outfall of the Reynolds Metals Co. Stations sampled in the Grasse River itself had higher sediment concentrations of alpha-chlordane than those directly in the mouth of the river (Figure 21). Gamma-chlordane was only found at stations 111 (upstream control) and 086, at 11 and 2 ug/kg, respectively.

DDT and its Metabolites: DDT was banned from major use by Ontario and the United States in the early 1970s. In Ontario, DDT use has been restricted to bat and mice control by permit only (MOE, 1982a). Along the north shore, with the exception of p,p'-DDE, sediment concentrations of DDT and its metabolites were close to or below their respective method detection limits, which ranged from 1 to 5 ug/kg. However, p,p'-DDE, one of the major degradation products of DDT, (Casarett and Doull, 1975) was detected at concentrations from 2 to 210 ug/kg (Figure 22). The highest level was found at station 094, in a slower moving section of the river near the Courtaulds/BCL outfalls, where fine-grained sediments with their associated contaminants seem to accumulate. Although p,p'-DDE was detected relatively frequently in Cornwall industrial and municipal effluent samples in 1979 and 1980, the greatest loadings of p,p'-DDE came from Domtar (Table 3c), which is located upstream of station 094. Since CIL, Domtar, Cornwall Chemicals, Courtaulds/BCL and the Cornwall WPCP do not produce or use p,p'-DDE, the identification of this compound in their effluents, and subsequently, to some degree in adjacent sediments, may indicate that other sources are present. Interestingly, although loadings of p,p'-DDT and p,p'-DDD (TDE) similar to those of p,p'-DDE came from some Cornwall effluents (Table 3c), only low levels were detected in downstream sediments (Figure 22). This may be due to more rapid degradation of DDT to DDD and DDE by bacteria in sediments.

DDT and its metabolite DDE were also detected at the mouth of the Raisin River, although the latter was predominant (3 to 10 ug/kg). This suggests upstream use and losses.

Generally, much higher concentrations of DDT and its metabolites were found in sediments along the south shore. The highest concentrations occurred in sediments near or downstream of the mouth of the Grasse and Raquette Rivers (Figure 22). However, while the concentrations of p,p'-DDT (120 ug/kg), p,p'-DDE (52 ug/kg) and p,p'-DDD (190 ug/kg) found at the depositional area (station 035) near the Reynolds Metals Co. outfall suggest recent local or Grasse River watershed inputs, elevated levels of o,p'-DDT (35 ug/kg) and p,p'-DDT (77 ug/kg) at upstream control station 111 also indicates recent upstream use and input of parent material, with later settling out of particulates downstream.

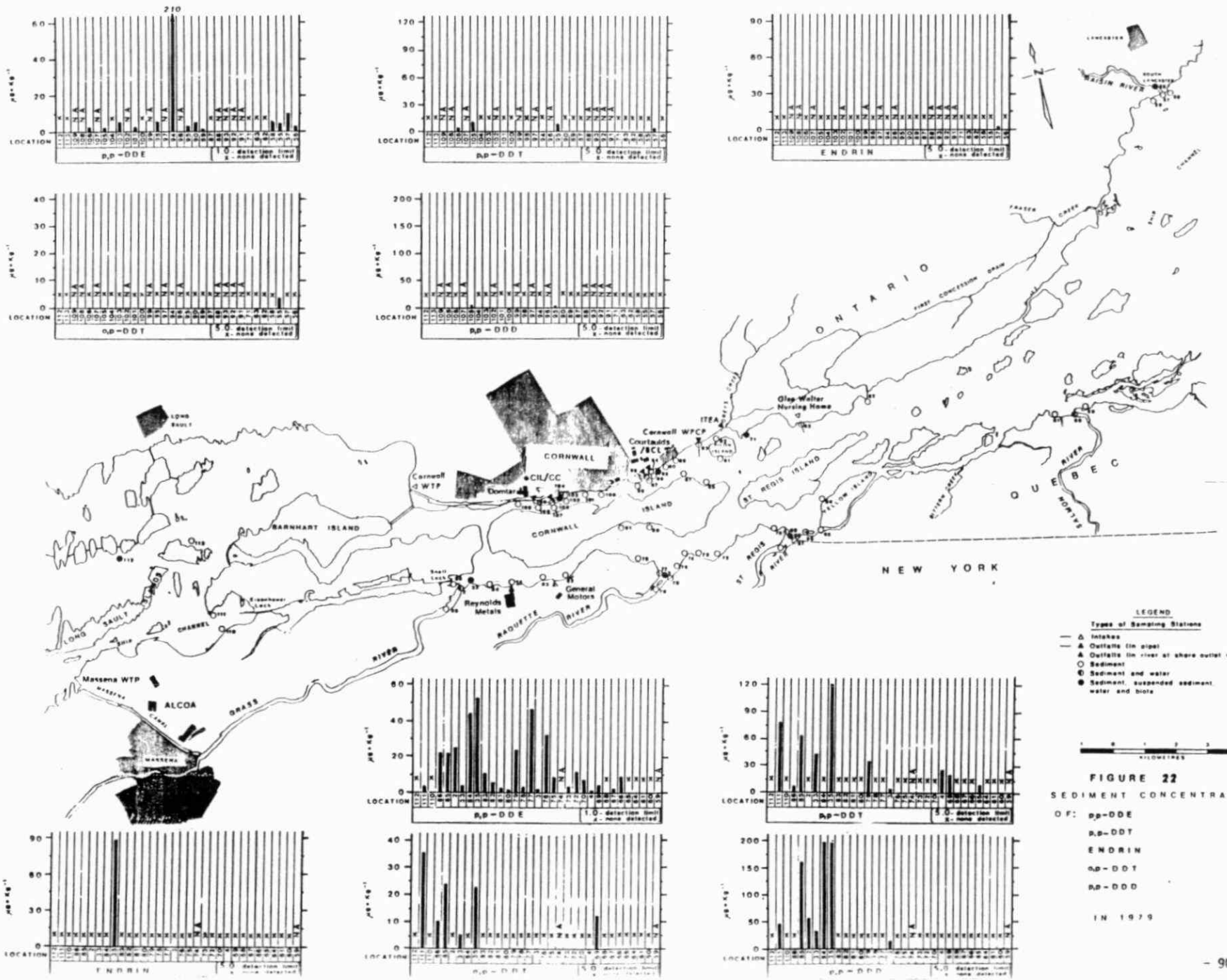


FIGURE 22

SEDIMENT CONCENTRATIONS

OF: p,p-DDE

p,p-DDT

ENDRIN

o,p-DDT

p,p-DDD

IN 1979

Endrin: Although endrin was found in some Cornwall effluents sampled in 1979 and 1980 (Table 3c), this compound was not found in Cornwall sediments. However, it was identified in the sediments of station 035 along the south shore, at a concentration of 89 ug/kg (Figure 22). The reason for this isolated detection is unclear, as is the relatively large loading from the Courtaulds/BCL facility in 1979 (Table 3c), since this pesticide is restricted in its use (MOE, 1982a). However, it may be related to suspected dieldrin inputs from the Grasse River (pg. 86), since endrin is a minor constituent of commercial dieldrin (Verschueren, 1977).

Hexachlorocyclohexane (BHC) Isomers: In Ontario, BHC is used in seed and soil treatment, foliar applications and for wood protection (restricted used only, MOE, 1982a). Pesticide grade BHC contains a mixture of isomers in the following amounts: alpha-isomer 55-70%; beta-isomer, 6-8%; gamma-isomer, 10-18%; delta-isomer, 3-4%; and epsilon-isomer, trace amounts (USEPA, 1980a). Of these, the gamma isomer (Lindane) is the most potent insecticide (Casarett and Doull, 1975). In 1979 and 1980, the major Cornwall dischargers of alpha (α), beta (β) and gamma (γ) - BHC were Domtar and the Cornwall WPCP, with total loadings for the three isomers being of the same order of magnitude (Table 3c). However high beta-BHC levels (30 and 37 ug/kg) were found only at stations 106 and 094 and not downstream of the Cornwall WPCP (Figure 23). Alpha- and gamma-BHC concentrations in sediments from these areas were not as greatly elevated as beta-BHC. This may be due to the fact that the alpha- and gamma-BHC isomers are metabolized more rapidly by microorganisms than the beta-isomer (Casarett and Doull, 1975).

The highest south shore sediment concentrations of beta- (29 ug/kg) and gamma-BHC (62 ug/kg) were found at the mouth of the Grasse River (Figure 23). The predominance of lindane (gamma-BHC) and almost complete absence of alpha-BHC in sediments from this area may reflect recent use and input to the watershed.

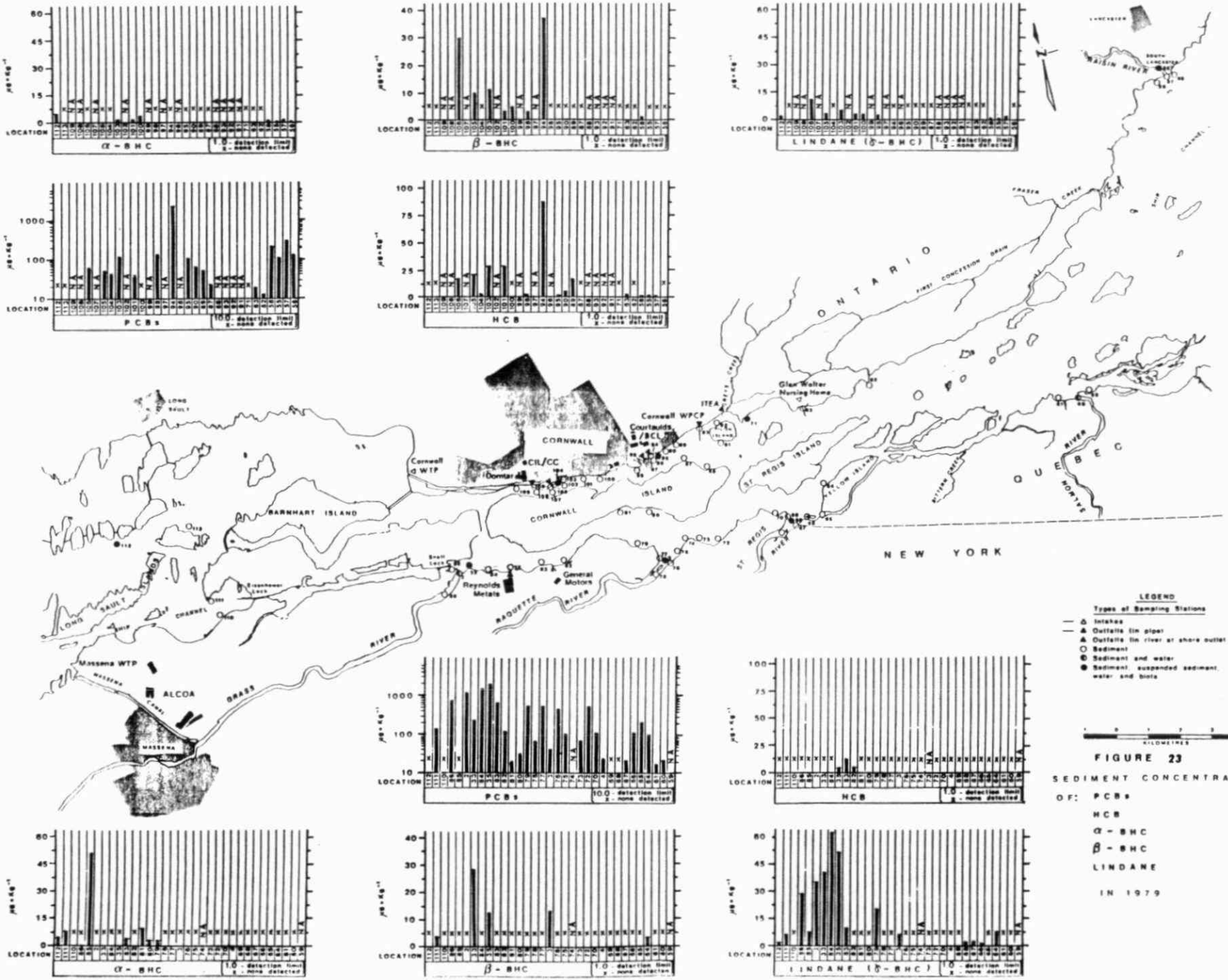


FIGURE 23

SEDIMENT CONCENTRATIONS OF: PCBs
HCB
α - BHC
β - BHC
LINDANE

IN 1979

Hexachlorobenzene (HCB): Although presently not a registered fungicide in Canada, HCB is used as a fungicide for cereal and seed treatment in the United States. It is also used as a plasticizer for polyvinylchloride (PVC); as a flame retardant; and in the manufacture of pentachlorophenol wood preservative. The highest concentration (87 ug/kg) of HCB was found in the sediments of station 094 along the north shore near the Courtaulds/BCL outfalls (Figure 23). Other stations downstream of the CIL/Cornwall Chemicals/Domtar combined diffuser also had detectable, but lower, concentrations of HCB (2-28 ug/kg). Effluent monitoring in 1979 and 1980 indicated that the major contributor of HCB loadings was Domtar, with lesser loadings from the Cornwall WPCP and the CIL/Cornwall Chemicals complex (Table 3c). The presence of this chlorinated aromatic in CIL and/or Cornwall Chemical effluents may be related to the fact that most HCB is generated as a by-product of the manufacture of chlorine and a number of chlorinated solvents such as carbon tetrachloride (USEPA, 1980b). However, the contributions from Domtar, the Cornwall WPCP and Courtaulds/BCL may have other sources, perhaps via the use of HCB-contaminated materials.

Along the south shore, HCB was only detected in the depositional area downstream of the Grasse River at levels of 3-15 ug/kg.

Polychlorinated Biphenyls (PCBs): While PCBs have been used in the past as stabilizers and plasticizers, and also in paints, rubber, asphalt, printer's ink, pesticides and hydraulic fluids, their use is now restricted to closed system electrical and heat transfer operations in Ontario.

PCBs were detected in all Cornwall effluents sampled in 1979 and 1980; however, the greatest loading came from Domtar (Table 3c). The highest concentration along the north shore (2,670 ug/kg) was found at station 094, a depositional area for fine-grained sediments (Figure 23). Concentrations at the remaining Cornwall area stations ranged from 140 ug/kg at station 098, also located in the vicinity of the Courtaulds/BCL outfalls, to not detectable at Farlinger's Point (station 071). The detection of PCBs in the Raisin River (station 058) at 240 ug/kg indicates upstream inputs. Although the watershed of this river is largely agricultural, it also receives some storm drainage from the north end of Cornwall and any leachate emanating from the City of Cornwall landfill site.

On the average, PCBs were found at somewhat higher concentrations along the south shore (348 ug/kg) than along the north shore (221 ug/kg) (Table 14). The highest concentrations were found at stations near or downstream of the Grasse River mouth, with a maximum concentration of 1,980 ug/kg in the depositional area near Reynolds Metals (station 035). Recent sampling of sediments by New York State personnel confirms these findings and the presence of PCB sources in the Massena area: elevated PCB levels were found close to the Reynolds Metals and General Motors foundry outfalls, while the highest concentration (49,000 ug/kg) was found in the Grasse River itself, just downstream of the ALCOA discharge at Massena (NYSDEC, 1981). The detection of this group of contaminants at lower levels in sediments at station 111 (150 ug/kg) indicates inputs from upstream of the Grasse River area as well.

Percentages of stations containing PCBs above the dredging guideline were similar for the north (61%) and south (64%) shores. The factors by which sediment PCB concentrations in the study area exceeded the current 50 ug/kg Provincial guideline for open-water disposal of dredged material are shown in Figures 24 and 25. At the north shore stations (Figure 24), PCB concentrations usually exceeded the guideline by a factor of 2 or less, the exception being the 53-fold exceedence at station 094 near the Courtaulds/BCL outfalls. On the south shore (Figure 25), although the maximum exceedence (40-fold at station 035 near Reynolds Metals Co. outfall) was somewhat lower, the average exceedence factor at the other stations was greater (7-fold).

PCB inputs from the Cornwall and Massena areas and from upstream sources had far-reaching impacts, as indicated by detectable levels in downstream sediments at the beginning of Lake St. Francis (e.g. stations 055 to 057 at the Raisin River and 060 and 061 at the Salmon River). This, as well as the overall differences between north and south shore PCB concentrations, is consistent with the results of sediment sampling conducted by Environment Canada in Lake St. Francis between 1979 and 1981: PCB concentrations were highest at the entrance to the lake, along the south shore; also, there was evidence of transport through the lake (Sloterdijk, 1983).

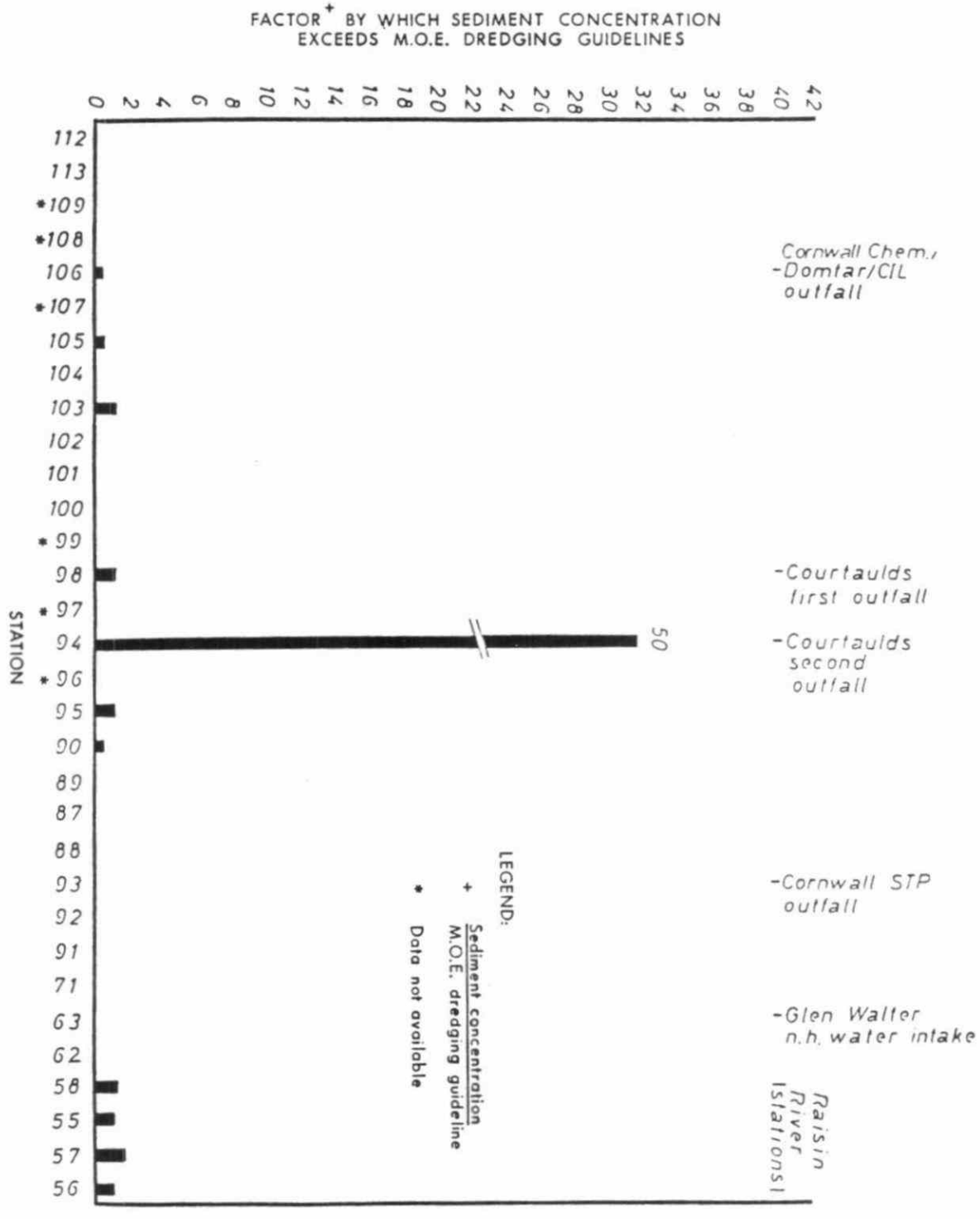


FIG. 24 The factor+ by which sediment PCB concentrations exceeded the M.O.E. dredging guideline at stations sampled along the north shore of the St. Lawrence River in 1970

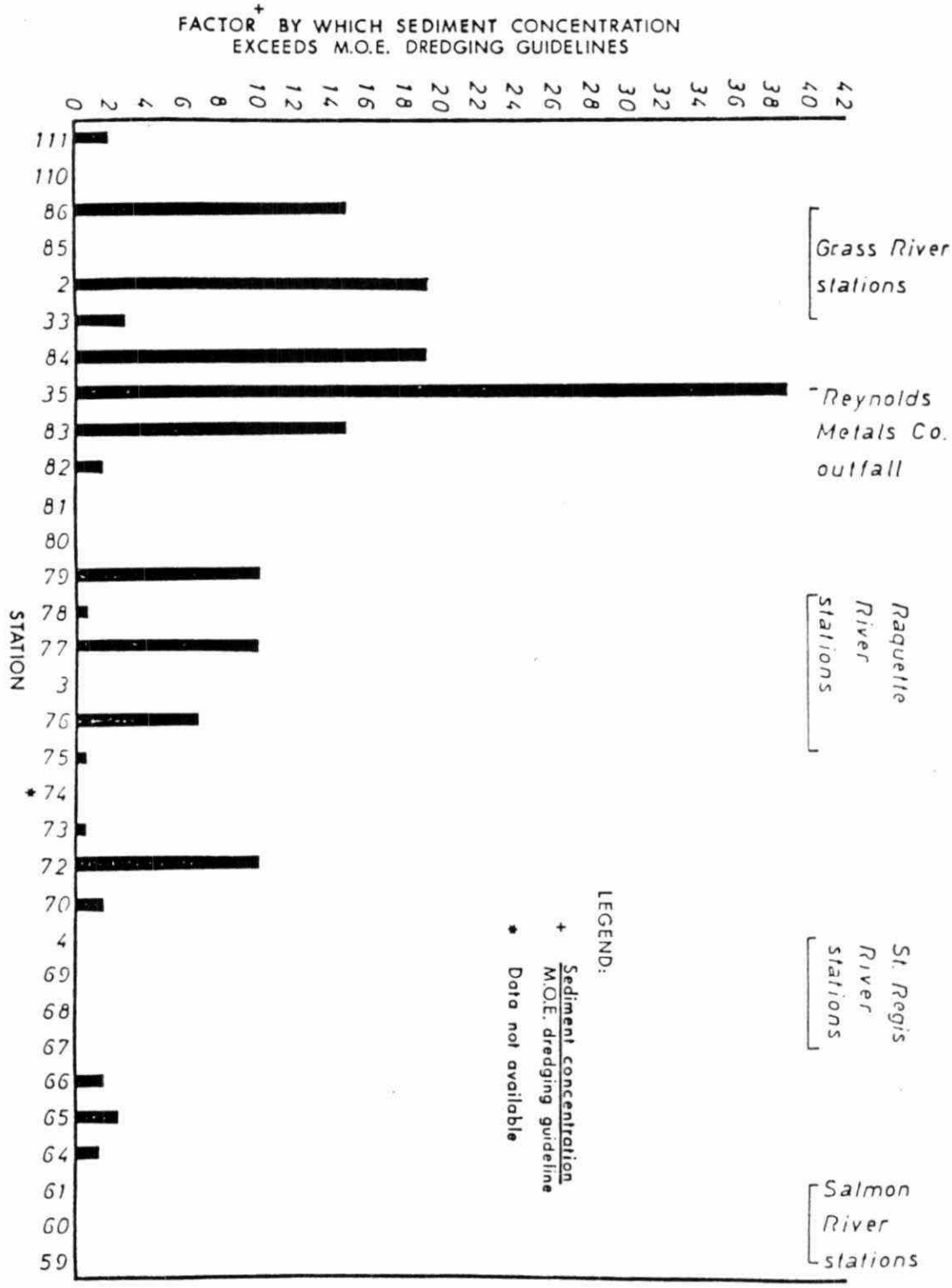


FIG. 25 The factor+ by which sediment PCB concentrations exceeded the M.O.E. dredging guideline at stations sampled along the south shore of the St. Lawrence River in 1979

Other Organochlorine Pesticides: Thiodan I and II (alpha- and beta-endosulfan), heptachlor and heptachlor epoxide were not detected in any of the 1979 sediment samples, although quantifiable loadings were noted for most of the Cornwall discharges sampled (Table 3c).

Mirex was not detected in any Cornwall effluent samples or in any sediments (detection limits: 0.005 ug/L and 5 ug/kg, respectively). However, levels below the MOE method detection limit (maximum: 3.3 ug/kg) were found in a few Lake St. Francis sediment samples (Sloterdijk, 1983), perhaps indicative of long-distance transport and inputs from Lake Ontario (Sloterdijk, 1984), which in turn receives mirex inputs from the Niagara River (Kuntz and Warry, 1983) and the Oswego River (Scrudato and Del Prete, 1982).

4.2.4.2.3 Ether Solubles

Ether solubles (more correctly termed solvent extractables or oils and greases) can include a wide variety of substances, including non-volatile petroleum hydrocarbons and their derivatives, vegetable oils, animal fats, soaps, greases and waxes.

Along the north shore, the highest concentrations of ether solubles (oils and greases) were found in sediments downstream of the Domtar/CIL/Cornwall Chemicals combined diffuser at stations 104 (13,838 ug/kg) and 106 (6,750 ug/kg) (Figure 26). These levels, as well as those in the Courtaulds/BCL area, exceeded the Provincial dredging guideline of 1,500 ug/kg. Of all north shore samples, 39% exceeded this guideline.

Along the south shore, the highest concentrations of this group of contaminants were found downstream of the confluence of the Grasse (2,078 ug/kg), Raquette (2,433 ug/kg) and St. Regis (3,100 ug/kg) Rivers with the St. Lawrence River. However, in contrast to the north shore samples, only 16% of sediment samples from this area exceeded the dredging guideline.

4.2.4.2.4 **Inorganic Contaminants**

The concentrations of cadmium, chromium, copper, iron, lead, mercury and zinc in sediments exceeded Provincial guidelines for open water disposal of dredged material (Persaud and Wilkins, 1976) at a number of stations.

Lead: Domtar and the Courtaulds/BCL complex were the major sources of lead along the north shore in 1979 (Table 3a) and this was reflected by the detection of elevated sediment lead levels in the vicinity and downstream of their outfalls and the fact that 26% of north shore samples exceeded the dredging guideline (Figure 26). Although the lead concentrations in sediments downstream of Domtar's outfall were below the guideline of 50 ug/g, lead levels near the Courtaulds/BCL outfalls (69-1,600 ug/g) exceeded the guideline. Decreasing concentrations of lead were detected further downstream. As with copper (see pg. 102), lead appears to be adsorbed to fine-grained materials which remain in suspension in the faster moving portion of the river, while sedimentation occurs in the vicinity of the Courtaulds/BCL outfalls, where current velocity is reduced.

Elevated lead levels were found in sediments associated with the Grasse, Raquette and St. Regis Rivers; however exceedence of the dredging guideline was only observed at station 086 (53 ug/g), located in the Grasse River.

Mercury: Sediments from 65% of stations along the north shore contained mercury concentrations exceeding the dredging guideline of 0.3 ug/g (Figure 26). This was due to past and present discharges of mercury from the CIL chlor-alkali plant (EPS, 1977), its past use as a slimicide by Domtar, and the introduction of mercury to the Cornwall WPCP from industries using the sewer system (MOE, 1977). While CIL was the largest contributor of mercury in 1979, the remaining discharges surveyed also contributed some mercury (Table 3a). The highest sediment concentrations were found immediately downstream of CIL (1.50 - 19.8 ug/g), near Courtaulds/BCL (1.30 - 18.0 ug/g) and at the Cornwall WPCP (0.52 - 1.80 ug/g).

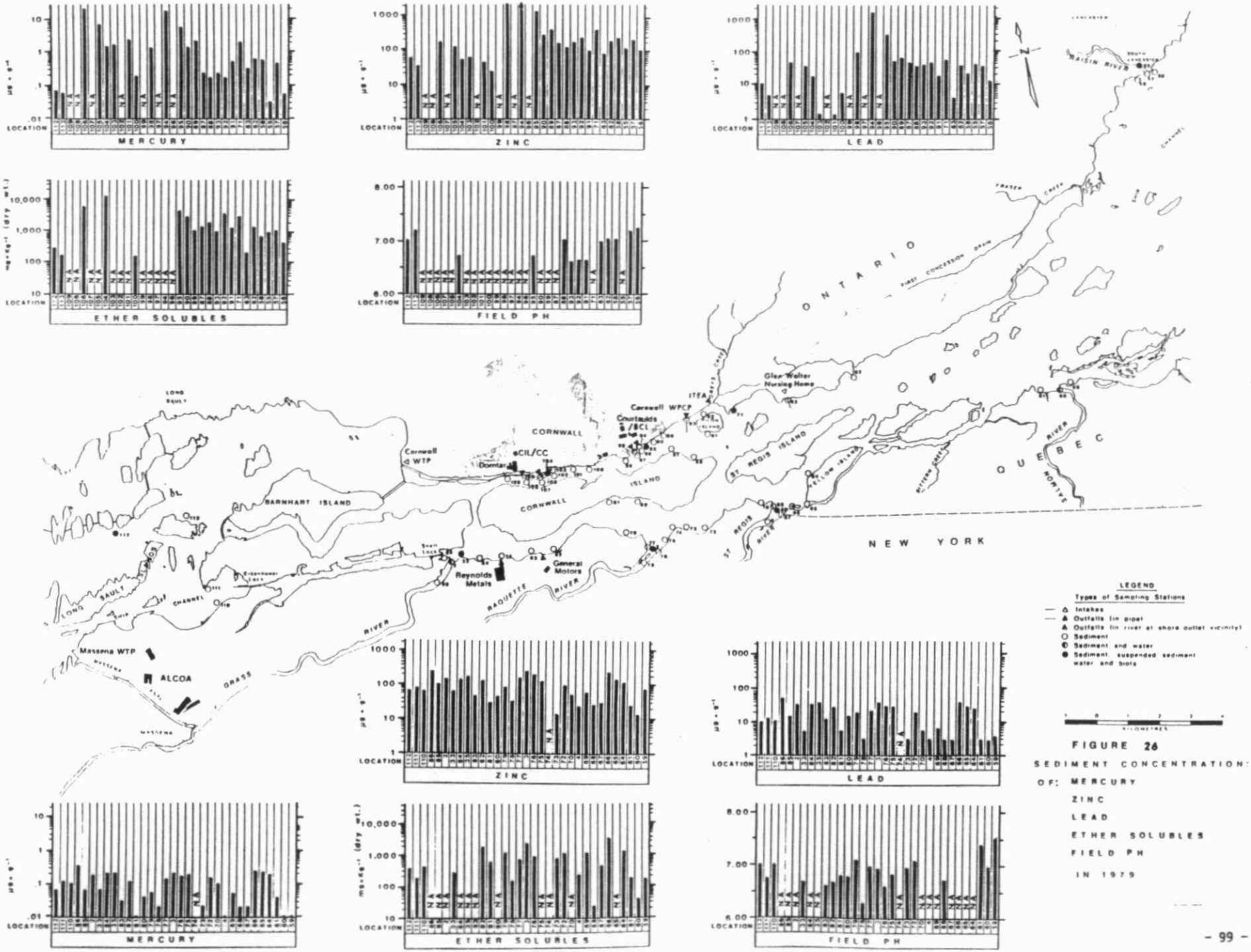


FIGURE 26

SEDIMENT CONCENTRATION OF: MERCURY
ZINC
LEAD
ETHER SOLUBLES
FIELD PH
IN 1979

In view of the reduction in mercury loadings from CIL since 1970, it was of interest to compare 1979 sediment mercury levels in the Cornwall area with results of the 1970 and 1975 studies (MOE, 1977). This proved difficult to accomplish on a station-by-station basis, owing to differences between surveys with respect to both sampling locations and sampling and collection methods. Therefore, average levels were determined for four selected areas, using only data for samples collected along the north shore (within about 60 m of shore). As shown in Table 15, a wide range of values were encountered for each area/year. However, between 1975 and 1979, there was a noticeable decline in the mean sediment mercury concentrations for areas 3 and 4 downstream of the CIL discharge, reflecting the reduction in mercury loadings from this facility (see section 3.1). Also evident for 1979 is a clear trend to declining levels with increasing distance downstream of the CIL discharge. A similar trend is evident for 1970 and 1975, although higher mean levels were found in area 3 than in area 2, which is immediately downstream of CIL. This may be related to the previous observation (see section 4.2.4.1) that the Courtaulds/BCL area is an area of deposition of fine-grained material.

Along the south shore, only one station (086) had a sediment mercury level (0.36 ug/kg) above the dredging guideline. This station is situated in the Grasse River.

The mean mercury sediment concentrations of the north (2.82 ug/g) and south (0.10 ug/g) shore stations reflect the impact of past and ongoing discharges of mercury in Cornwall. This impact was also evident further downstream, in the more highly contaminated sediments along the northern part of Lake St. Francis (Sloterdijk, 1983) indicating that contaminant deposition in river sediments is largely temporary, and that transport and resuspension processes gradually move these materials downstream into Lake St. Francis. Furthermore, contaminant and sediment particle size distributions in this lake indicate that most toxic substances entering the lake eventually move through it and out towards Montreal (Sloterdijk, 1983).

TABLE 15
COMPARISON OF SEDIMENT MERCURY CONCENTRATIONS (ug/g) ALONG THE NORTH SHORE OF THE ST. LAWRENCE RIVER - 1970, 1975 and 1979

AREA/LOCATION	YEAR		
	1970	1975	1979
1. Upstream of Cornwall	0.20* (0.06-0.29)	0.04 (0.02-0.09)	0.09 (0.06-0.12)
2. 0-1.4 km downstream of CIL	4.70 (0.85-14.50)	5.69 (0.05-18.2)	6.80 (1.50-19.8)
3. 3-5 km downstream of CIL (in vicinity of Courtaulds/BCL	14.23 (1.24-35.85)	9.51 (0.62-44.0)	5.40 (1.30-18.0)
4. 6-14 km downstream of CIL (area around & downstream of Pilon Island)	5.87 (4.00-7.74)	1.87 (0.20-5.87)	0.68 (0.16-1.80)

* Values are means of samples in each area (range of values in brackets).

Zinc: The relatively higher loadings of zinc from Courtaulds/BCL than from Domtar (Table 3a) were reflected by concentrations in the sediments near their outfalls (Figure 26) as well as by water quality objective exceedences near the former (section 4.2.1.2). Sediments from just downstream of the Domtar outfall had zinc concentrations (120-190 ug/g) above the 100 ug/g dredging guideline. Zinc discharged by Domtar is probably also transported downriver and deposited near the Courtaulds/BCL outfalls. The highest concentrations (410-4100 ug/g) were found in the area of the river near the Courtaulds/BCL complex.

Although water quality exceedences of zinc were only identified at the mouth of the Raquette River in 1979 (section 4.2.1.2), concentrations above the dredging guideline were observed in sediments associated with the Grasse River (150 to 250 ug/g), Raquette River (120 to 210 ug/g) and St. Regis River (110 to 230 ug/g) discharges, as well as in the vicinity of the Reynolds Metals (180 ug/g) and General Motors (110 ug/g) discharges. This data would suggest south shore inputs, principally via the tributaries.

Copper: Domtar and the Cornwall WPCP contributed the largest loadings of copper along the north shore in 1979 (Table 3a), and this was reflected by water quality (section 4.2.1.2) and exceedences of the 25 ug/g dredging guideline in downstream sediments (Figure 27). The highest sediment concentrations were found immediately downstream of Domtar (59 ug/g), at stations near the Courtaulds/BCL outfalls (530 and 110 ug/g) and in a small bay downstream of the WPCP (54 ug/g). This distribution suggests the deposition of particulate-associated copper in slower moving areas downstream.

Along the south shore, several stations in and downstream of the Grasse River had sediment concentrations of copper which exceeded the guideline, with the level at station 086 (110 ug/g) exceeding it by a factor of four. This and exceedences of the copper water quality objective at the mouth (section 4.2.1.2) indicate upstream copper inputs in the river basin.

Cadmium: Elevated concentrations of cadmium were found in sediments downstream of the major source in 1979 (Domtar). However, the highest levels (as well as those exceeding the 1.0 ug/g dredging guideline) were found in the Courtaulds/BCL area (1.80 ug/g) and at the mouth of the Raisin River (5.70 ug/g), indicating downstream transport of particulate-associated material as well as tributary input (Figure 27).

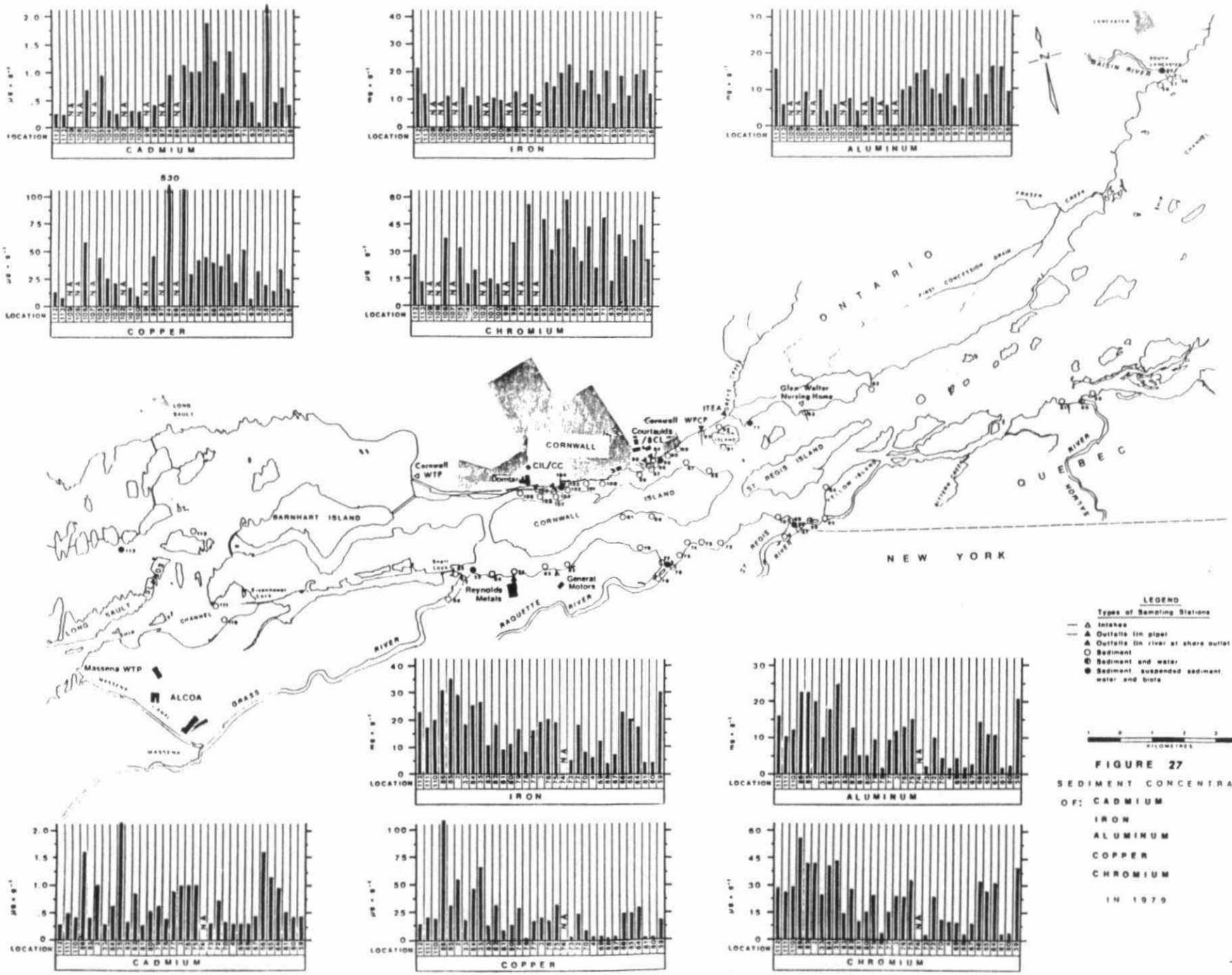


FIGURE 27

SEDIMENT CONCENTRATIONS OF: CADMIUM
IRON
ALUMINUM
COPPER
CHROMIUM
IN 1979

Along the south shore, elevated sediment cadmium levels were again associated with the discharge from the three major tributaries, with concentrations downstream of the Grasse (2.10 ug/g) and St. Regis Rivers (1.60 ug/g) being the highest. These values reflect the water quality data (section 4.2.1.2) and suggest ongoing inputs from these watersheds.

Chromium: Concentrations of chromium (Figure 27) were elevated above background in sediments downstream of the major Cornwall sources in 1979 (Domtar and the Cornwall WPCP). However, the highest levels were found in the vicinity of Courtaulds/BCL (55 ug/g) and across the channel at Cornwall Island (59 ug/g), reflecting downstream transport and settling out of particulate-associated chromium. These concentrations were only slightly higher than the dredging guideline of 50 ug/g.

Chromium was also elevated at the mouths of the tributaries along the south shore, being highest in sediments of the Grasse River (56 ug/g). While this distribution suggests inputs in these watersheds, this could not be confirmed by the water quality data, since the analytical detection level did not allow a distinction between these samples and those from upstream stations (section 4.2.1.2).

Iron: Concentrations of iron (Figure 27) were above the dredging guideline of 10 mg/g at the upstream control stations (12 to 21 mg/g), reflecting the influence of relatively high percentages of clay (6% to 31%) in these sediments (Appendix, Table XVI). However, the elevated levels at and downsiream of Courtaulds/BCL (12 to 23 mg/g) suggest an additional influence from the major Cornwall point sources of this element (Domtar, Courtaulds/BCL and the Cornwall WPCP).

Along the south shore, iron was above both background and the dredging guideline levels in sediments near the mouths of the Grasse (18 to 31 mg/g), Raquette (16 to 19 mg/g), St. Regis (17 to 23 mg/g) and Salmon Rivers (30 mg/g). These trends were also evident in water samples (Figure 13) and suggest inputs or the transport of particulate-associated material (e.g. clays). The highest concentration of iron, 35 mg/g, was found at the outlet of the Snell Lock, just upstream of the Grasse River mouth.

Aluminum: The sediment distribution patterns of aluminum were quite similar to those of iron (Figure 27), reflecting the fact that these two elements are normal components of sediments.

While evaluated sediment concentrations of aluminum may be related to the natural presence of fine-grained material (e.g. clays) it is worth noting that the highest levels in sediment and water samples (see section 4.2.1.2) were found at the mouth of the Grasse River (downstream of ALCOA) and near the outfalls of Reynolds Metals and General Motors. All of these are facilities which produce products composed of aluminum (see section 3.2).

4.2.4.2.5 Other Organics and Inorganics

Table 16 summarizes the results of full-scan GS/MS analyses of Cornwall effluents and a selected number of suspended solids and bottom sediment samples collected in 1979. Since internal standards were not available at the time of analysis, this summary is qualitative, indicating only the station and matrix the compound was identified from. Although major sources for the contaminants detected could not, in most instances, be unequivocally identified, it is probable that the majority of the compounds were introduced to the system via nearby point source discharges and urban runoff, although long-distance transport (atmospheric or aqueous) may also be a contributing factor.

Table 16 contains a large number of identified and unidentified compounds, and many of the former have no available guidelines, criteria or standards and little may be known about their ecological effects. Nevertheless, this list can provide some direction for future studies in this section of the St. Lawrence River. Certain compounds (see Table 16) have been identified by the USEPA as priority pollutants or by the MOE as chemicals for further evaluation (i.e. phenol, diethyl phalate, dibutyl phthalate, dioctyl phthalate). Some of the other organic compounds may also be strongly hydrophobic, as indicated by their detection in bottom and/or suspended sediment samples. Since they may also be lipophilic these should also be investigated.

TABLE 16
GC/MS - IDENTIFIED COMPOUNDS FOUND IN EFFLUENT, SUSPENDED SEDIMENTS AND BOTTOM SEDIMENT SAMPLES COLLECTED IN 1979.

Class/Compound	References	Effluent	Suspended Sediment	Sediment
Hydrocarbons, unidentified		C,Cc,Co,D,Ca, Cs,Cv,W,I	104,095,071,055 033,003,068	104,071
Cyclohexane derivatives, unidentified	MOE	Cc,Co,D,Ca, Cv,W,I	104,068	
Aromatic Hydrocarbons:				
C3 alkyl benzene		D,Co,Cv,I		071
C4 alkyl benzene		D,Co,Cv,I		
C5 alkyl benzene		I		
Nitrobenzene	MOE,EPA	I		
C2 alkyl styrene		D		
Methyl styrene		I		
1,1-cyclohexylidene-bis-benzene			068	
Chlorinated Aromatics:				
Dichlorobenzene	MOE,EPA	Co,Cc		
Trichlorobenzene	MOE,EPA	I		
Tetrachlorobenzene		I		
Polynuclear Aromatic Hydrocarbons:				
Acenaphthene	MOE,EPA			104
Anthracene	MOE,EPA			104
Anthraquinone		W		071
Benzo(k) fluoranthene	MOE,EPA			071
Hydroxy biphenyl		W		
Diphenyl diamine		W		
Naphthalene	MOE,EPA	D		
Decahydronaphthalene		C		
C2 alkyl naphthalene			095	
Methyl naphthalene		D,W	104,095	104
Dimethyl decahydro naphthalene		D		
Nitronaphthalene		Co		
Trimethylnaphthalene		D		
Octahydro-1,1,4-trimethyl naphthalene		W		
Pyrene/Fluoranthene	MOE,EPA	D		104,071
Methyl pyrene				071
C4 alky phenanthrene				104
Unidentified				071

Table 16 continued

Class/Compound	References	Effluent	Suspended Sediment	Sediment
Heterocyclic Hydrocarbons:				
Benzothiazole	MOE	Cs,I		
Benzothiazole derivative		Cv		
Mercapto benzothiazole		D,W		
Indole		W		
Methyl indan		I		
Dihydro indan		Cv,I		
Dihydrotrimethyl phenyl indan		W		
Methyl tetralin		D		
Dimethyl tetralin		D		
Trimethyl tetralin		D		
Alcohols:				
Ethyl hexanol		W		
Benzene ethanol	MOE	W		
Dimethyl benzene ethanol		I		
Dimethyl benzyl alcohol		I		
Unidentified		D,Co,Ca,Cs, W,I	104,095,071, 055,033,003, 068	104,071
Camphor alcohol		W		
Ethers:				
Diphenyl ether		W		
Tetrachloro diphenyl thioether		I		
Esters:				
C16;ene		W		
Benzene acetic acid, methyl ester		W		
C20 dienoic acid, methyl ester			033	104
Methyl esters		D		
Unidentified		W,I		
Ketones/Aldehydes:				
Methyl acetone				
Acetophenone		W		
Methyl acetophenone		I		
Hexamethyl tetrahydro-5-indocane-1,7-dione				104
Hydroxyfuranyl ethanone		D		
Trimethylcyclopentenone		D		
Camphor (1,7,7-trimethyl-bicyclo [2.2.1]-2-heptanone)		W		
Oxacyclotetradecan-2-one			055	
Vanillin (3-methoxy-4-hydroxy-benzaldehyde)		D		

Table 16 continued

Class/Compound	References	Effluent	Suspended Sediment	Sediment
Methoxy vanillin		D		
Unidentified		D,Ca,Cv,W,I	104,071,055, 003,068	
Di-t-butylcyclohexadiene-dione		Co,Cv		
Phenols:				
Phenol	MOE,EPA	D	104	104
C9/C10 phenol		Cs,I		
2,6-di-t-butyl phenol		Cv		
Di-t-butylmethyl phenol		D,Cv,W,I	104,095,055, 033,003,068	104,071
Cresol	MOE	D,W		
Unidentified		Cs		
Phthalates:				
Diethyl phthalate	MOE,EPA	W	104,033	
Dibutyl phthalate	MOE,EPA	C	055	
Dioctyl phthalate	MOE,EPA	C,Cc,D,Co,Ca, Cs,Cv,W,I	104	
Unidentified		Cs,Cv,W	068	104,071
Organic Acids:				
C5		Cv		
C6			104	
C8		I		
C9		W,I		
C10		Cv,W,I		
C12		D,Cv,W	104,095	
C14		D,Cv,W,I	104,095,071, 055,033,003, 068	104
C15		D,W	104,095,071,	104
C16		D,Cv,W,I	055,033,003, 068	
C17		D	104,033	071
C18		D,W,I	104,095,071, 055,033,003, 068	071
C18 diene			104,071	
C22			104,071,068	071
C23			068	
C24			068	
Benzene acetic acid			104	
Benzoic acid		W	104,095	

Table 16 continued

Class/Compound	References	Effluent	Suspended Sediment	Sediment
Benzoic acid derivative		I		
Methyl benzoic acid		W		
Barbituric acid		Cv		
Hydroxy benzene acetic acid		I		
Dimethyl octahydrophenanthrene carboxylic acid		D		104,071
Ethyl hexanoic acid		W		
Bis (2-ethyl hexyl) butene dioic acid		I	095	
Benzene propionic acid		W		
Cresotic acid		W		
Unidentified		W,I	033	071
Sulphides:				
Sulphide		D		
Benzene sulphonamide		D		
Dimethyl disulphide		W		
Dimethyl trisulphide		D		
Miscellaneuos:				
Glycols, unidentified		C,D,Co,Cs,W,I	104,033,068	
Caffeine		W		
Cholestene		W		
Cholesterol		W	033	
Cholestan-3-ol		W		
Steroid, unidentified		D,Cv	033	
Limonene (p-Menth-1,8-diene)		W		
Menthol		W		
Terpene		Cv,W		
α-Terpineol(p-Menth-1-en-8-ol)		Cs,W		
1,2,4-trithiolane		Cv		
1,3,5-trithane		Cv		
1,2,4,6-tetrathioprene		Cv		
Urea derivative		Cs		
Silicon		C,C,Cc,D,Co, Cs,Cv,I,W		071
Sulphur		D,Ca,Cs,Cv,W	104,095,055, 003,068	104,071

Code to effluent samples (see Figure 2):

D = Domtar C = CIL Cc = Cornwall Chemicals
Co = Cornwall Canal Ca = Courtaulds/BCL acid Cs = Courtaulds/BCL sulphide
Cv = Courtaulds/BCL viscose W = Cornwall WPCP I = ITEA

Code to sediment samples: locations as per Figure 3.
EPA = USEPA Priority Pollutant (Keith and Telliard, 1979).
MOE = Chemicals for Further Evaluation (MOE, 1982b).

4.2.5 Biota

During the 1979 survey, benthic macroinvertebrates and macrophytes were collected at 8 stations (112, 104, 095, 055, 033, 068 and 071). Fauna (e.g. snails) associated with macrophytes were also collected. The species identified and their contaminant levels are listed in Appendix Table XVII. For comparative purposes, however, the PCBs, mercury and zinc results were averaged for macrophytes and macroinvertebrates at each station and are presented along with available data for suspended sediments, bottom sediments and water samples in Figures 28, 30 and 32. PCB and mercury levels in young-of-the-year spottail shiners collected in the area during the fall of 1979, are also included. In addition to the 1979 fish data, PCB levels in 1980 and 1981 spottails are also included in Figure 29 (K. Suns, MOE, personal communication) as is mercury trend data on Lake St. Francis walleye in Figure 31 (A. Johnson, MOE, personal communication).

PCBs: Along the north shore, spatial trends in average PCB levels in the macroinvertebrate population reflected the concentrations in bottom sediments (Figure 28). Levels of PCBs in water (as discussed in Section 4.2.1.3.2) were below detection, although PCBs were detected in the particulate fraction.

The highest levels of PCBs were found in biota and suspended solids from the mouth of the Grasse River. Spottail shiners, macroinvertebrates and macrophytes contained mean PCB levels of 2072, 158 and 25 ng/g, respectively, at station 033 in 1979. This coincides with New York State data on sport fish collected in the Massena area in 1979: PCBs levels were elevated in samples of fish from the Grasse River (below Massena) and the St. Lawrence River downstream of the mouth of the Grasse River (NYSDEC, 1981). Ontario data showed that, while PCBs in sport fish from downstream Lake St. Francis were below Health and Welfare Canada's unrestricted consumption guideline of 2 mg/kg, levels exceeded the guideline in two commercially-fished species (sturgeon and catfish) (MOE/MNR, 1980).

The relative magnitude of PCB contributions and bioavailability on the two sides of the river is further illustrated by 1979 data on minnows from downstream Lake St. Francis: mean concentrations in the south shore population were about 2-3 times higher than those from the north shore (Sloterdijk, 1984).

Figure 28: Levels Of PCBs In Biota (ng/g wet wt.), Sediments (ng/g dry wt.) And Water (ng/L) Collected From The Cornwall-Massena Reach Of The St. Lawrence River (1979)

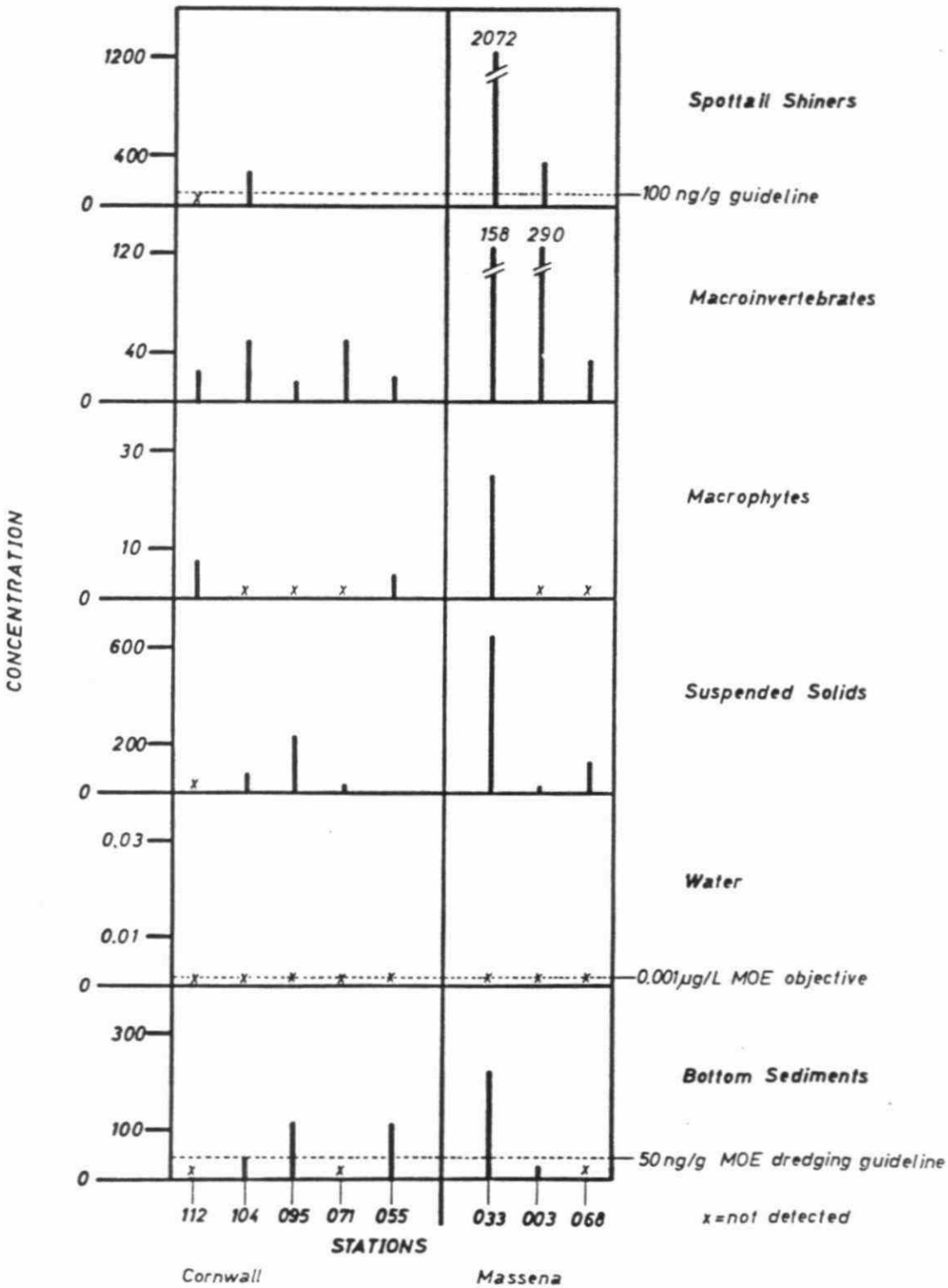
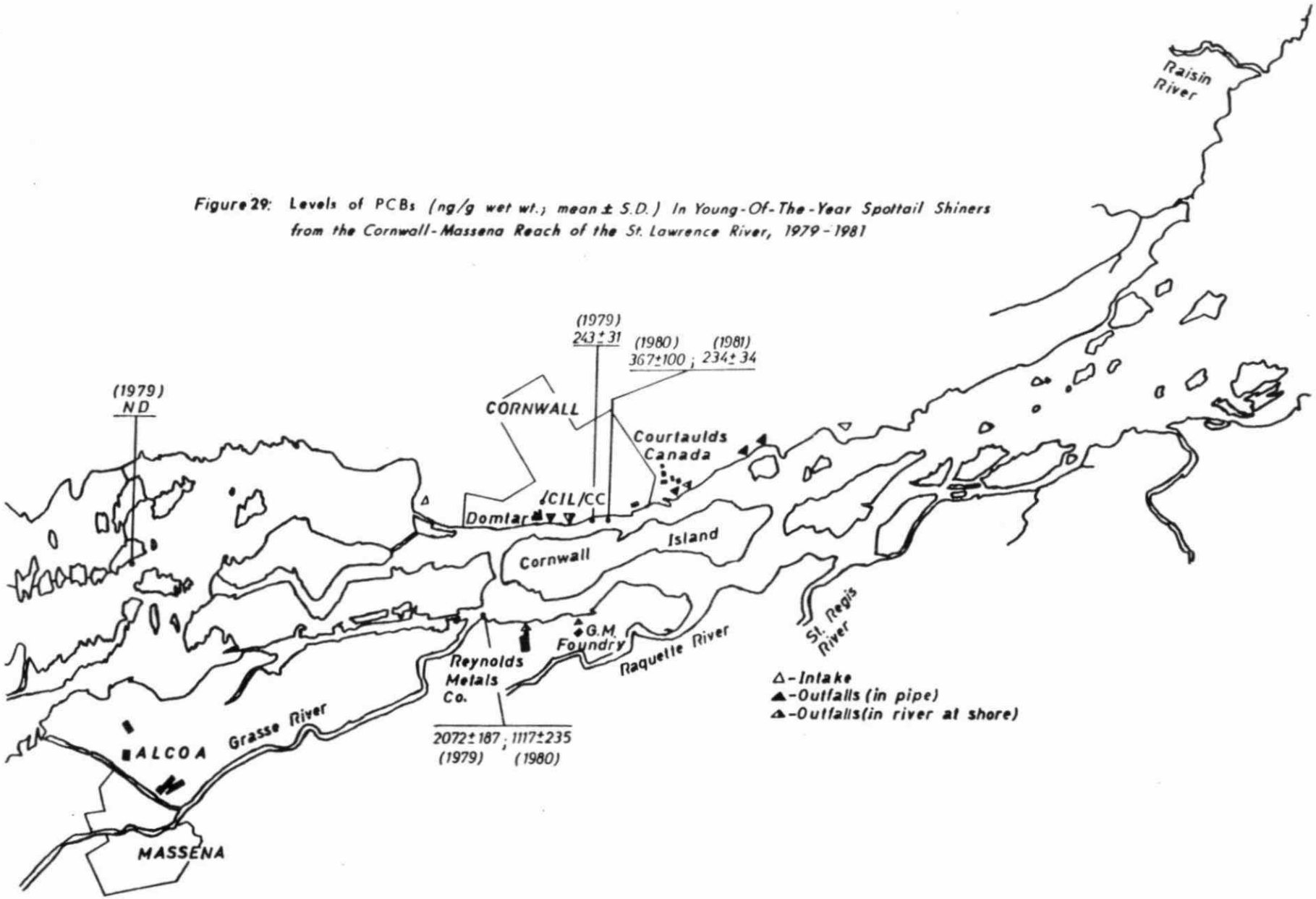


Figure 29: Levels of PCBs (ng/g wet wt.; mean ± S.D.) In Young-Of-The-Year Spottail Shiners from the Cornwall-Massena Reach of the St. Lawrence River, 1979-1981

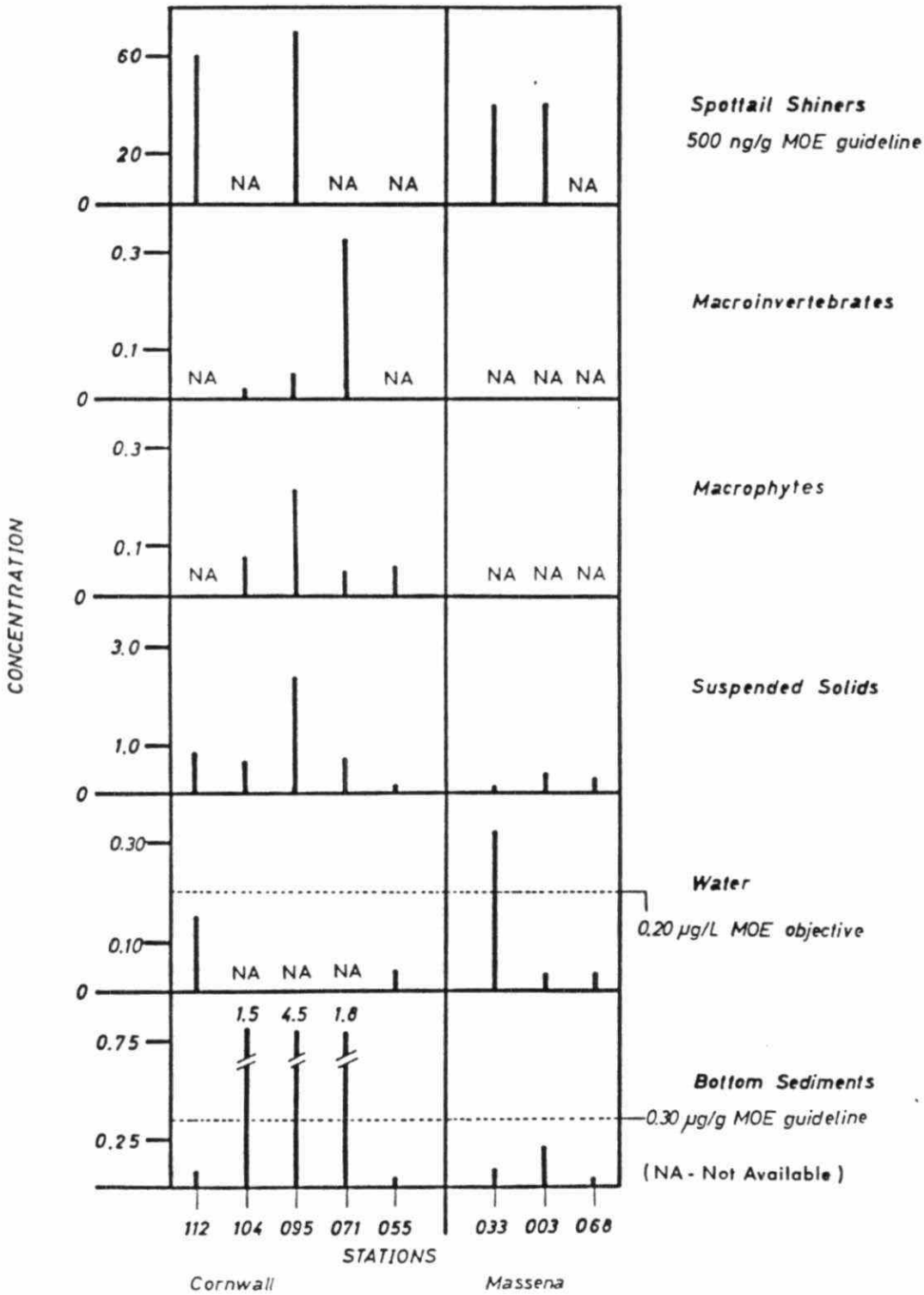


In the Cornwall area, no significant change occurred in the mean concentrations of PCBs in spottail shiners between 1979, 1980 and 1981 (243, 367 and 234 ng/g, respectively - see Figure 29). These fish, although containing five times less PCBs than those caught at the mouth of the Grasse River, were still above the GLWQA objective (100 ng/g) for the protection of fish-eating birds (IJC, 1978b). Since the collection site is just downstream of the Domtar/CIL/Cornwall Chemicals outfall, the lack of a decline in tissue levels suggests that no major change has occurred in the loadings of PCBs to this area. However, significant declines of PCB inputs may have occurred in the Grasse River between 1979 and 1981 as indicated by mean levels in spottail shiners collected at the mouth (2,072 declining to 1,117 ng/g). Nevertheless, even the 1981 level was still substantially above the Agreement objective.

Mercury: Unfortunately, macrophyte and macroinvertebrate data was unavailable for the south shore stations due to insufficient sample material for mercury analysis, making comparisons between the north and south shores difficult. Nevertheless, mercury concentrations were somewhat higher in spottail shiners from the north shore than the south shore (Figure 30), reflecting the levels in bottom and suspended sediments and Cornwall loadings (Table 3a). However, levels of mercury in the fish were all well below the GLWQA (IJC, 1978b) and Provincial (MOE, 1978) objectives of 500 ng/g for the protection of fish-consuming birds.

Along with elevated bottom sediment concentrations of mercury at station 095, there was a corresponding increase in levels in suspended solids and macrophytes (2.4 ug/g and 0.2 ng/g, respectively); however, concentrations in benthic macroinvertebrates were most elevated further down river (0.3 ng/g) at station 071 (located downstream of Pilon Is. and the Cornwall WPCP). This elevated average results from the mercury level (0.68 ng/g) found in amphipods from this site (Appendix, Table XVII). These organisms were not found at station 095. The presence of mercury in spottail shiners from the control station (112) at 60 ng/g suggests the influence of upstream contaminant inputs.

Figure 30: Levels Of Mercury In Biota (ng/g wet wt.), Sediments (µg/g dry wt.) And Water (µg/L) Collected From The Cornwall - Massena Reach Of The St. Lawrence River (1979)



Mercury trend data for walleye from Lake St. Francis (Figure 31) indicate a significant decline since 1970 when reductions in chloro-alkali plant mercury discharges were instituted (OWRC, 1970). However, average edible tissue levels have not yet reached the 0.5 ppm federal consumption guideline limit. This is in contrast to the Lake St. Clair walleye population, average levels of which are now (as of 1984) about 0.5 ppm (MOE/MNR, 1986) and reflect the cessation of mercury discharges at the Sarnia Dow Chemical plant. Although there may be differences between the two lakes which influence the rate of decline in mercury, this comparison suggests that to achieve the 0.5 ppm objective in Lake St. Francis walleye, mercury discharges should be eliminated at the Cornwall CIL plant.

Zinc: The high loadings of zinc from Domtar and Courtaulds/BCL were reflected in the correspondingly high values found in biota near the outfalls of the latter (Figure 32). The swift current near the Domtar/CIL/Cornwall Chemicals outfall would carry the zinc in the same manner as mercury, with deposition occuring near station 095. This is borne out by differences in bottom sediment concentrations of zinc between station 104 (near the Domtar outfall) and 095 (near the Courtaulds/BCL outfalls) (100 ug/g vs 1500 ug/g) respectively. These concentration differences also appear in macroinvertebrate and macrophyte zinc levels. For example, at station 104, average macroinvertebrate and macrophyte levels were 32 and 53 ug/g, while at station 095 they were 150 and 351 ug/g, respectively.

Along the south shore, zinc was most elevated in macroinvertebrates from the Raquette River mouth (300 ug/g), reflecting the pattern of zinc in suspended solids (Figure 31). In contrast, macrophyte levels of zinc were highest at the Grasse River mouth (100 ug/g).

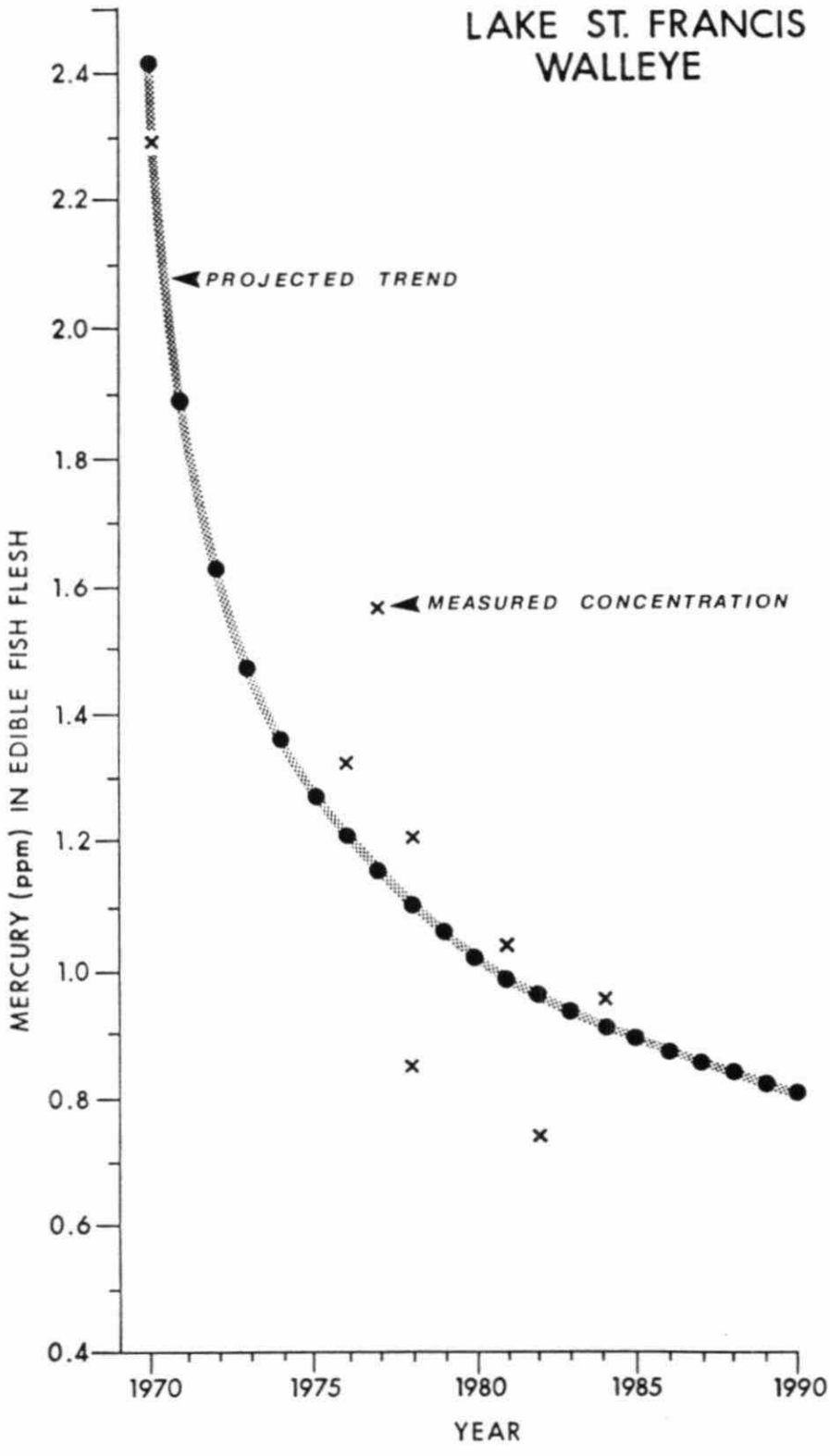
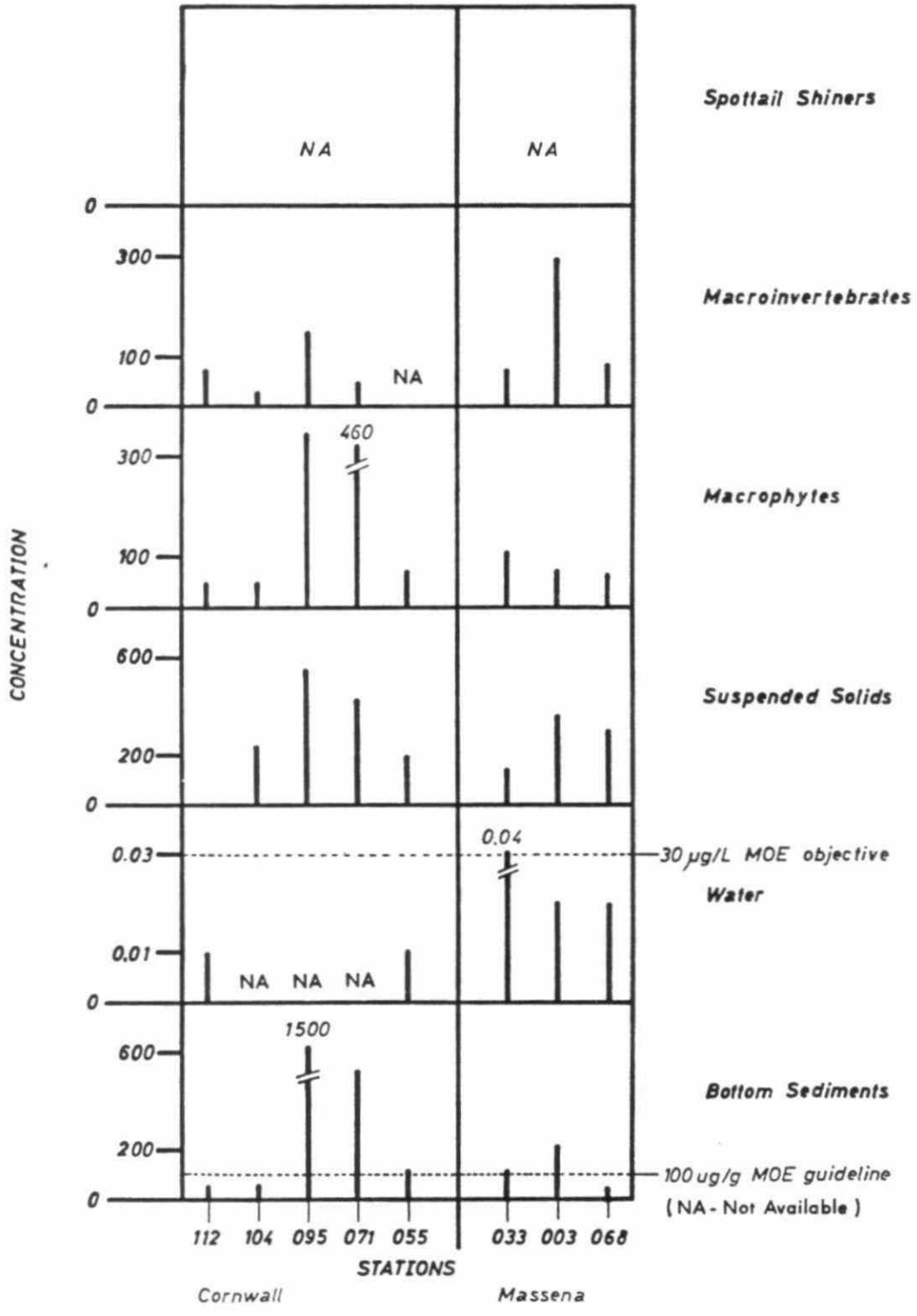


FIG. 31 Trends in Mercury Content (ppm = µg/g wet wt.) in edible Portion (dorsal musculature) of Lake St. Francis Walleye, 1970-1984

Figure 32: Levels Of Zinc In Biota (µg/g wet wt.), Sediments (µg/g dry wt.) And Water(mg/L) Collected From The Cornwall-Massena Reach Of The St. Lawrence River (1979)



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APPENDIX

APPENDIX

TABLE I Summary of Meteorological Data for 1979 Cornwall Survey (Survey days and week prior to beginning of Survey).

TABLE II Summary of Meteorological Data for 1980 Cornwall Surveys (Survey days and week prior to beginning of Survey).

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TABLE X Pseudomonas aeruginosa Concentrations (organisms/100 mL) in St. Lawrence River Surface Waters (1.5 m depth) during 1980.

TABLE XI Fecal Streptococcus Concentrations (organisms/100 mL) in Cornwall Influent and Final Effluents Sampled during 1980 Surveys.

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TABLE XII *Pseudomonas aeruginosa* Concentrations (organisms/100 mL) in Cornwall Influent and Final Effluents Sampled during 1980 Surveys.

TABLE XIII Fecal Coliform Concentrations (organisms/100 mL) in St. Lawrence River Surface Waters (1.5 m depth) during 1982 Surveys.

TABLE XIV Fecal *Streptococcus* Concentrations (organisms/100 mL) in St. Lawrence River Surface Waters (1.5 m depth) during 1982.

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TABLE XVII Contaminants Concentrations in Biota from the Cornwall-Massena area, 1979.

TABLE XVIII Current Speed (cm. sec^{-1}) and Direction (degrees from north) of St. Lawrence River surface waters (1.5 m depth) during August 6-9, 1982 survey.

FIGURE I Mean Current Speech and Direction (1.5 m depth) during August 6-9, 1982 survey.

TABLE I.
SUMMARY OF METEOROLOGICAL DATA FOR 1979 CORNWALL SURVEY
(Survey days and week prior to beginning of survey).

Date	Cornwall Water Treatment Plant - Met. Station		
	Air Temp., °C		Precipitation mm.
	max.	min.	
September 14	17.0	15.0	110.0
September 15	17.0	10.0	0.0
September 16	20.0	11.0	0.0
September 17	23.5	12.0	0.0
September 18	23.5	16.0	13.0
September 19	10.0	4.0	0.0
September 20	15.5	2.0	0.0
September 21	20.0	12.0	1.1
October 22	16.0	9.5	0.3
September 23	15.0	2.5	0.0
September 24	19.0	3.0	0.0
September 25	21.0	8.5	0.0
September 26	19.0	12.5	0.0
September 27	23.0	6.5	0.0
September 28	19.0	13.0	2.2
September 29	20.0	14.0	0.0
September 30	20.0	11.5	0.0
October 1	19.0	15.5	Trace

TABLE II
SUMMARY OF METEOROLOGICAL DATA FOR 1980 CORNWALL SURVEYS
(SURVEY DAYS AND WEEK PRIOR TO BEGINNING OF SURVEY)

Date	Cornwall Water Treatment Plant - Met. Station			MOE Survey Vessel		
	Air Temp. °C max.	min.	Precipitation mm	Air Temp. °C	Wind Speed $km.h^{-1}$	Prevailing Wind Direction, Degrees
Jun. 17	21.0	8.0	0.0			
18	21.0	10.0	3.0			
19	21.5	10.5	0.0			
20	18.0	14.0	2.8			
21	27.0	13.0	0.0			
22	27.0	13.0	0.0			
23	28.0	15.0	0.0			
24	31.0	19.0	0.0	29.7	22	270 (W)
25	31.0	19.5	0.6	26.0	15	270 (W)
26	28.0	20.0	2.0	21.6	31	210 (SSW)
Jul. 22	22.0	20.0	0.0			
23	24.0	18.0	0.0			
24	27.0	14.0	0.0			
25	28.0	15.0	1.8			
26	26.0	19.0	0.0			
27	26.5	20.0	0.0			
28	28.0	20.0	0.0			
29	26.0	20.0	29.7	21.2	0	000 (N)
30	26.5	18.5	7.0	23.4	9	210 (SSW)
31	28.0	16.5	0.0	22.1	19	230 (WSW)
Sep. 2	26.5	16.0	15.0			
3	23.0	15.0	0.0			
4	24.0	13.0	0.0			
5	26.5	19.0	0.0			
6	23.5	16.5	0.0			
7	21.5	12.5	0.0			
8	20.0	9.0	0.0			
9	24.0	9.0	18.0	23.0	9	195 (SSW)
10	18.0	9.5	0.0	20.7	34	270 (W)
11	22.0	12.5	0.4	18.0	39	230 (WSW)
Oct. 14	6.5	1.5	0.0			
15	9.0	-2.5	0.0			
16	10.5	-1.0	0.0			
17	21.0	1.0	5.2			
18	20.0	11.5	0.0			
19	11.5	8.0	2.2			
20	6.0	4.0	0.0			
21	7.0	1.0	4.4	7.2	22	200 (SSW)
22	4.5	0.0	0.0	4.0	19	310 (WNW)
23	5.0	-3.0	0.0	7.0	9	000 (N)
Nov. 18	0.0	-5.0	2.0			
19	1.0	-8.0	0.0			
20	6.0	-3.5	0.0			
21	8.0	0.0	0.3			
22	6.0	1.0	0.0			
23	8.0	1.0	1.0			
24	5.0	3.0	16.0			
25	2.5	-1.5	2.2+3.2(snow)	-	-	-
26	-1.0	-7.0	0.0	-	-	-
27	-2.0	-9.0	0.0	-	-	-

- No data available.

TABLE III
SUMMARY OF METEOROLOGICAL DATA FOR 1982 CORNWALL SURVEYS
(Surveys days and week prior to beginning of survey)

Date	Cornwall Water Treatment Plant - Met. Station		
	Air Temp., °C		Precipitation mm.
	max.	min.	
August 1	26.0	17.0	1.0
August 2	17.0	13.5	0.0
August 3	22.0	10.0	0.0
August 4	25.0	15.0	1.3
August 5	24.0	15.0	0.0
August 6	25.5	12.0	0.0
August 7	28.0	15.0	1.8
August 8	27.0	18.5	23.8
August 9	28.0	19.0	0.0
September 21	19.0	10.0	0.0
September 22	19.0	11.0	0.0
September 23	17.5	9.0	22.2
September 24	20.0	10.0	0.0
September 25	21.0	12.0	0.0
September 26	19.0	10.0	0.0
September 27	14.5	13.0	16.8
September 28	17.0	13.0	0.6
September 29	16.0	6.0	0.0
September 30	23.0	9.0	0.0

TABLE IV
ST. LAWRENCE RIVER FLOW RATES*
(m^3/sec) DURING 1979, 1980 and 1982 SURVEYS

YEAR	SURVEY PERIOD	FLOW $\bar{x} \pm SD$
1979	Sept. 21 - Oct. 13	8,186 ± 110
1980	June 24 - 26	8,160 ± 0
	July 29 - 31	8,160 ± 0
	Sept. 9 - 11	8,640 ± 0
	Oct. 21 - 23	8,010 ± 0
	Nov. 25 - 27	7,840 ± 0
1982	Aug. 6 - 9	7,970 ± 17
	Sept. 28 - 30	7,560 ± 0

* Measured by Cornwall gauge at Moses-Saunders Dam (source: Ontario Surface Water Data. publ. by Inland Waters Directorate, Water Resources Branch, Water Survey of Canada, Ottawa, Canada).

TABLE V
FLOW RATES (m^3/day) OF CORNWALL EFFLUENTS SAMPLED
DURING 1979 SURVEYS

Sampling Date	Domtar outfall	CIL outfall	Courtaulds/BCL			Cornwall Chem.	Cornwall STP	Itea
			Acid	Sulphate	Viscose			
September 21	141,900	2,620	7,040	2,070	7,720	910	51,000	90
September 25	141,600	2,260	7,080	1,790	8,440	910	43,400	90
September 26	144,000	2,310	6,530	1,790	6,640	910	43,000	90
September 28	141,600	2,300	7,620	1,960	6,530	910	42,700	90

TABLE VI
FLOW RATES (m^3/day) OF CORNWALL EFFLUENTS SAMPLED
DURING 1980 SURVEYS

Sampling Date		Domtar outfall	CIL outfall	Brookdale Ave. combined sewer	Cornwall STP effluent
June	24	89,800	3,283	-	36,300
	25	85,700	2,979	-	36,730
	26	80,500	3,170	-	37,830
	$\bar{x}$	85,333	3,144	-	36,953
	S.D.	4,661	154	-	789
July	29	140,300	3,761	34,696	66,170
	30	138,400	3,302	-	53,310
	31	143,500	3,602	-	44,440
	$\bar{x}$	140,733	3,555	-	54,640
	S.D.	2,577	233	-	10,925
September	9	122,800	3,743	4,983	53,430
	10	124,200	3,652	-	44,890
	11	122,600	3,283	-	41,960
	$\bar{x}$	123,200	3,559	-	46,760
	S.D.	872	244	-	5,969
October	21	114,300	2,390	-	43,520
	22	114,700	2,622	-	41,180
	23	123,400	2,686	-	38,200
	$\bar{x}$	117,467	2,566	-	40,967
	S.D.	5,142	156	-	2,666
November	25	Mill down	2,817	33,779	66,090
	26	" "	2,518	15,924	39,350
	27	" "	2,549	14,795	39,800
	$\bar{x}$	-	2,628	21,499	48,413
	S.D.	-	164	10,649	15,310

$\bar{x}$ = Mean
S.D. = Standard Deviation

TABLE VII
FLOW RATES (m^3/day) OF CORNWALL EFFLUENTS SAMPLED
DURING 1982 SURVEYS

Sampling Date	Domtar Effluent	CIL/Cornwall Chemicals Effluent	Brookdale Ave. Combined Sewer*	Cornwall STP Effluent
August 6	124,000	3,300	-	32,140
7	124,000	3,300	-	36,700
8	124,000	3,750	9,100	56,320
9	128,900	4,100	-	46,790
$\bar{x}$	125,225	3,613	-	42,988
S.D.	2,450	388	-	10,792
Sept. 28	128,700	3,700	-	59,040
29	125,400	3,550	-	52,290
30	142,500	3,300	-	47,280
$\bar{x}$	132,200	3,517	-	52,870
S.D.	9,071	202	-	5,901

* - Effluent not sampled for bacteriological analysis.
$\bar{x}$ - mean
S.D. - Standard Deviation

TABLE VIII
FECAL COLIFORM CONCENTRATIONS (ORGANISMS/100 mL) IN ST. LAWRENCE RIVER SURFACE WATERS (1.5 m DEPTH) DURING 1980

DATE SAMPLED	STATION NUMBER										
	054A	054B	055	056A	056B	057	058A	059	060A	061A	061B
June 24	16	4	8	8	4	4	4	4	16	52	<4
25	20	12	4	8	4	4	4	12	32	108	12
26	4	8	12	16	4	16	20	4	144	60	8
Gm	11	7	7	10	4	6	9	8	42	70	<7
S.D.	15	6	6	5	0	8	8	3	87	33	-
July 29	70,000	2,900	40,000	140,000	9,000	2,500	18,000	14,000	4,000	2,700	280
30	15,000	3,900	9,000	4,500	7,900	15,000	17,000	14,000	19,000	2,800	2,800
31	17,000	7,700	11,000	15,000	12,000	11,000	10,000	16,000	4,100	2,600	900
Gm	26,134	4,016	15,821	21,142	9,485	7,444	14,518	14,637	6,780	2,699	890
S.D.	35,351	3,297	19,726	99,829	2,262	11,954	5,558	1,173	9,771	102	1,925
Sept. 9	>1,500	>1,500	>1,500	>1,500	250	190	620	-	260	1,200	<10
10	570	170	330	510	680	210	130	450	630	210	<10
11	1,400	900	1,500	1,100	1,600	≈60	170	160	570	360	140
Gm	>1,062	>612	>906	>944	648	≈134	239	268	454	449	<11
S.D.	-	-	-	-	993	-	313	-	283	648	-
Oct. 21	21,000	26,000	900	28,000	22,000	>1,500	4,900	18,000	>1,500	12,000	500
22	23,000	18,000	26,000	19,000	27,000	20,000	26,000	19,000	21,000	5,000	3,000
24	21,000	12,000	8,200	11,500	13,000	8,500	5,800	5,600	14,000	3,800	≈300
Gm	21,647	17,775	5,768	18,290	19,766	>6,341	9,041	12,419	>7,612	6,109	≈766
S.D.	1,167	8,393	26,094	10,284	9,051	-	13,616	12,346	-	5,029	-
Nov. 25	<100	<100	<10	<100	<100	<100	≈30	<100	≈100	≈800	<100
26	≈10	≈10	<10	<10	<10	<10	≈20	≈10	100	300	<10
27	≈20	<10	<10	≈10	<10	190	970	420	330	1,900	≈10
Gm	≤27	≤22	<10	≤22	<22	<57	≈83	≤75	≈149	≈770	≤22
S.D.	-	-	-	-	-	-	-	-	-	-	-

TABLE VIII Continued

DATE SAMPLED	STATION NUMBER									
	062A	062B	063A	063B	063C	064	065A	066A	066B	(Grasse R.) 002
June 24	32	8	4	4	<4	<4	<4	-	-	4
25	24	8	4	12	<4	<4	<4	-	-	-
26	40	8	96	<4	<4	<4	80	-	-	32
Gm	31	8	12	<6	<4	<4	<11	-	-	11
S.D.	31	0	60	-	-	-	-	-	-	-
July 29	3,100	680	560	720	520	116	320	-	-	92
30	9,000	630	800	1,200	960	600	900	-	-	-
31	2,100	8,000	14,000	1,400	700	160	190	-	-	≈70
Gm	3,884	1,508	1,844	1,065	704	223	380	-	-	≈80
S.D.	4,366	4,892	8,923	380	253	311	458	-	-	-
Sept. 9	1,100	260	330	80	<10	10	<10	-	-	<10
10	560	≈40	550	460	≈10	≈70	-	-	-	-
11	190	≈60	420	280	≈60	530	≈40	-	-	≈50
Gm	489	≈85	424	218	≤18	72	≤20	-	-	≤22
S.D.	697	-	123	318	-	-	-	-	-	-
Oct. 21	15,000	1,200	26,000	6,500	21,000	15,000	27,000	-	-	~20
22	4,000	3,000	2,800	6,000	2,100	5,000	3,800	-	-	-
24	8,700	8,400	9,500	4,500	≈200	2,200	1,100	-	-	<100
Gm	8,052	3,115	8,843	5,599	≈2,066	5,485	4,833	-	-	≤45
S.D.	7,593	5,132	18,151	1,194	-	8,885	19,434	-	-	-
Nov. 25	<100	<100	≈100	≈100	<100	<100	≈200	<10	≈30	490
26	≈70	≈40	≈30	≈10	≈40	<10	<10	-	≈10	≈20
27	120	≈10	100	≈70	≈40	≈90	≈20	≈20	≈20	3,200
Gm	≤94	≤34	≈67	≈41	≤54	≤45	≈63	≤20	≈18	≈315
S.D.	-	-	-	-	-	-	-	-	-	-

Gm = Geometric Mean
S.D.= Standard Deviation
- = No sample, no analysis, or S.D. could not be calculated
≈ = Approximately

TABLE IX
FECAL STREPTOCOCCUS CONCENTRATIONS (ORGANISMS/100 mL) IN ST. LAWRENCE RIVER SURFACE WATERS (1.5 m DEPTH) DURING 1980

DATE SAMPLED	STATION NUMBER										
	054A	054B	055	056A	056B	057	058A	059	060A	061A	061B
June 24	16	<4	<4	12	4	<4	<4	52	<4	<4	<4
25	8	4	<4	<8	<4	<4	<4	<4	<4	4	<4
26	16	12	12	12	8	4	4	28	8	4	4
Gm	13	<6	<6	<8	<5	<4	<4	<18	<5	<4	<4
S.D.	6	-	-	-	-	-	-	-	-	-	-
July 29	156	36	44	3,600	32	36	60	156	120	<4	<4
30	40	<100	<100	<100	<100	<100	100	<100	<100	<100	100
31	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	80
Gm	<85	<71	<76	<330	<68	<71	<84	<116	<106	<34	<32
S.D.	-	-	-	-	-	-	-	-	-	-	-
Sept. 9	≈10	<10	≈10	<10	<10	<10	<10	-	≈10	≈50	<10
10	≈40	≈20	≈30	≈40	≈20	≈40	≈30	≈30	≈50	≈20	<10
11	≈20	≈20	≈30	≈80	≈30	≈40	≈40	≈90	110	<10	≈20
Gm	≈20	≤16	≈21	≤32	≤18	≤25	≤23	≈60	≈38	≤22	≤13
S.D.	-	-	-	-	-	-	-	-	-	-	-
Oct. 21	10	<10	<10	<10	≈10	≈20	<10	≈20	≈50	<10	<10
22	<100	<100	<100	<100	≈100	<100	<100	<100	<100	<10	≈10
24	<100	<100	<100	<100	<100	<100	<100	<100	<100	1,200	<100
Gm	≤46	<46	≤46	<46	≤46	≤58	<46	≤58	≤79	<49	≤22
S.D.	-	-	-	-	-	-	-	-	-	-	-
Nov. 25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-	-
S.D.	-	-	-	-	-	-	-	-	-	-	-

TABLE IX Continued

DATE SAMPLED	STATION NUMBER									
	062A	062B	063A	063B	063C	064	065A	066A	066B	(Grasse R.) 002
June 24	<4	8	8	4	<4	<4	8	-	-	8
25	<4	4	<4	<4	<4	<4	4	-	-	-
26	4	16	16	4	12	<4	292	-	-	4
Gm	<4	8	<16	<4	<6	<4	21	-	-	6
S.D.	-	8	-	-	-	-	190	-	-	-
July 29	<4	<4	4	64	48	<4	132	-	-	40
30	40	10	30	<10	<10	<10	10	-	-	-
31	<100	100	20	10	10	<10	<10	-	-	170
Gm	<25	<16	13	<19	<17	<8	<24	-	-	82
S.D.	-	-		-	-	-	-	-	-	-
Sept. 9	<10	≈20	<10	<10	<10	<10	≈10	-	-	≈20
10	≈30	<10	≈20	<10	≈20	≈10	-	-	-	-
11	≈30	≈30	≈10	≈30	≈20	≈20	≈10	-	-	≈80
Gm	≤21	≤18	≤13	≤14	≤16	≤13	≈10	-	-	≈40
S.D.	-	-	-	-	-	-	-	-	-	-
Oct. 21	≈10	<10	<10	<10	<10	≈10	<10	-	-	<10
22	<10	<10	<10	<10	<10	≈100	<10	-	-	-
24	<100	<100	<100	<100	<100	<100	<100	-	-	<100
Gm	≤22	<22	<22	<22	<22	≤46	<22	-	-	<32
S.D.	-	-	-	-	-	-	-	-	-	-
Nov. 25	-	-	-	-	-	-	-	<4	4	766
26	-	-	-	-	-	-	-	<4	-	<10
27	-	-	-	-	-	-	-	<4	4	360
Gm	-	-	-	-	-	-	-	<4	4	<140
S.D.	-	-	-	-	-	-	-	-	-	-

Gm = Geometric Mean
S.D.= Standard Deviation
- = No sample, no analysis, or S.D. could not be calculated
≈ = Approximately

TABLE X
PSEUDOMONAS AERUGINOSA CONCENTRATIONS (ORGANISMS/100 mL) IN ST. LAWRENCE RIVER SURFACE WATERS (1.5 m DEPTH) DURING 1980

DATE SAMPLED	STATION NUMBER										
	054A	054B	055	056A	056B	057	058A	059	060A	061A	061B
June 24	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
25	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
26	20	34	32	66	14	6	24	42	2	2	4
Gm	<6	<5	<5	<6	<5	<3	<5	<6	<2	<2	<3
S.D.	-	-	-	-	-	-	-	-	-	-	-
July 29	16	6	6	118	8	<2	6	10	6	<2	2
30	<2	<2	<2	6	4	8	<2	8	32	<2	<2
31	<2	<2	<2	<2	<2	4	<2	2	4	<2	<2
Gm	<5	<3	<3	<11	<4	<4	<3	5	9	<2	<2
S.D.	-	-	-	-	-	-	-	8	17	-	-
Sept. 9	<2	<2	<2	<2	<2	<2	<2	-	4	<2	<2
10	<2	<2	<2	<2	<2	<2	2	<2	8	2	<2
11	<2	<2	<2	<2	<2	<2	<2	<2	14	2	<2
Gm	<2	<2	<2	<2	<2	<2	<2	<2	8	<2	<2
S.D.	-	-	-	-	-	-	-	-	6	-	-
Oct. 21	-	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-	-
S.D.	-	-	-	-	-	-	-	-	-	-	-
Nov. 25	-	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-	-
S.D.	-	-	-	-	-	-	-	-	-	-	-

TABLE X Continued

DATE SAMPLED	STATION NUMBER									
	062A	062B	063A	063B	063C	064	065A	066A	066B	(Grasse R.) 002
June 24	<2	<2	2	<2	<2	<2	<2	-	-	2
25	<2	<2	<2	<2	<2	<2	<2	-	-	-
26	<2	4	16	14	8	<2	4	-	-	8
Gm	<2	<3	<5	<5	<6	<2	<3	-	-	4
S.D.	-	-	-	-	-	-	-	-	-	-
July 29	<2	2	2	<2	<2	<2	<2	-	-	<2
30	14	4	8	2	2	<2	4	-	-	-
31	2	<2	<2	<2	<2	<2	<2	-	-	<2
Gm	<5	<3	<6	<2	<2	<2	<3	-	-	<2
S.D.	-	-	-	-	-	-	-	-	-	-
Sept. 9	<2	<2	<2	<2	<2	<2	<2	-	-	<2
10	<2	<2	<2	<2	<2	<2	-	-	-	-
11	<2	<2	<2	<2	<2	<2	<2	-	-	<2
Gm	<2	<2	<2	<2	<2	<2	<2	-	-	<2
S.D.	-	-	-	-	-	-	-	-	-	-
Oct. 21	-	-	-	-	-	-	-	-	-	-
22	-	-	-	-	-	-	-	-	-	-
24	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-
S.D.	-	-	-	-	-	-	-	-	-	-
Nov. 25	-	-	-	-	-	-	-	-	-	-
26	-	-	-	-	-	-	-	-	-	-
27	-	-	-	-	-	-	-	-	-	-
Gm	-	-	-	-	-	-	-	-	-	-
S.D.	-	-	-	-	-	-	-	-	-	-

Gm = Geometric Mean
S.D.= Standard Deviation
- = No sample, no analysis, or S.D. could not be calculated

TABLE XI
FECAL STREPTOCOCCUS CONCENTRATIONS (organism/100 mL) IN CORNWALL INFLUENT AND FINAL EFFLUENTS SAMPLED DURING 1980 SURVEYS

Sampling Date		Cornwall WTP(raw)	Domtar	CIL	Brookdale Ave. combined sewer	Cornwall WPCP
June	24	<2	<300	<10	-	-
	25	-	444	<8	-	>600
	26	-	640	≈10	-	>1,500
	Gm	-	<440	≤9	-	>949
July	29	2	2,500	1,720	800*	8,000,000
	30	-	<10,000	100	-	20,000
	31	-	1,500,000	<100	-	66,000,000
	Gm	-	<33,471	<276	-	2,193,923
September	9	<2	2,600	<10	-	2,500
	10	-	4,200	∿70	-	17,000
	11	-	4,700	290	-	7,000
	Gm	-	3,716	≤59	-	6,676
October	21	6	3,400	<100	-	2,400
	22	-	2,000	<10	-	8,900
	23	-	<10,000	<100	-	6,200
	Gm	-	<4,082	<46	-	5,097
November	25	<2	-	≈10	-	4,100
	26	-	-	≈10	-	>300
	27	-	-	≈10	-	2,000
	Gm	-	-	≈10	-	>1,350

Gm = Geometric Mean
* = Only sampled during overflow event
"-" = No sample (or not calculated). Note: Domtar shut down during November survey.

Cornwall WTP raw water data courtesy of J. Bates, City of Cornwall.

TABLE XII

PSEUDOMONAS AERUGINOSA CONCENTRATIONS (organism/100 mL) IN CORNWALL INFLUENT AND FINAL EFFLUENTS SAMPLED DURING 1980 SURVEYS

Sampling Date		Cornwall WTP(raw)	Domtar	CIL	Brookdale Ave. combined sewer	Cornwall WPCP
June	24	-	8	<4	-	-
	25	-	<2	<4	-	26
	26	-	24	24	-	28
	Gm	-	<7	<11	-	27
July	29	-	220	74	44*	>600
	30	-	100	108	-	<10
	31	-	200	<2	-	>1,500
	Gm	-	164	<25	-	>703
September	9	-	20	<2	-	40
	10	-	~70	<2	-	<10
	11	-	<10	6	-	2
	Gm	-	≤24	<3	-	9
October	21	-	-	-	-	-
	22	-	-	-	-	-
	23	-	-	-	-	-
	Gm	-	-	-	-	-
November	25	-	-	-	-	-
	26	-	-	-	-	-
	27	-	-	-	-	-
	Gm	-	-	-	-	-

Gm = Geometric Mean
* = Only sampled during overflow event
"-" = No sample (or not calculated). Note: Domtar shut down during November survey.

TABLE XIII
FECAL COLIFORM CONCENTRATIONS (organisms/100 mL) IN ST. LAWRENCE
RIVER SURFACE WATERS (1.5m depth) DURING 1982

DATE SAMPLED	STATION NUMBER										
	072B	066B	054A	054B	054C	056A	056B	058A	058B	058C	059A
Aug. 6	-	≈20	65,000	10,000	1,300	11,000	≈20	900	≈60	≈10	-
7	-	≈20	20,000	800	800	7,000	700	60,000	900	<10	-
8	-	1,000	60,000	500	1,100	30,000	<10	10,000	≈60	<10	-
9	-	≈900	16,000	≈200	<100	10,000	≈100	90,000	<100	≈300	-
Gm	-	≈137	33,424	≈946	<582	12,328	≈61	14,848	≤134	≤23	-
S.D.	-	-	35,813	-	-	10,681	-	106,223	-	-	-
Sept. 28	30	20	40	30	30	100	20	150	40	<10	50
29	<10	20	40	20	30	1,800	100	12,000	30	<10	41,000
30	20	70	70	20	20	7,000	40	15,000	1,000	80	22,000
Gm	<18	30	48	23	26	1,080	43	13,416	200	<20	3,560
S.D.	-	33	19	6	33	8,378	54	26,845	546	-	141,425

TABLE XIII Continued

DATE SAMPLED	STATION NUMBER									
	060A	060B	060C	071A	071B	061A	061B	062A	062B	062C
Aug. 6	20,000	-	-	-	-	-	300	30,000	1,100	<10
7	90,000	-	-	-	-	-	1,200	60,000	13,000	500
8	90,000	-	-	-	-	-	800	80,000	80,000	≈10
9	240,000	-	-	-	-	-	2,100	50,000	3,000	<100
Gm	78,964	-	-	-	-	-	882	51,800	7,654	<47
S.D.	141,248	-	-	-	-	-	1,121	26,437	41,733	-
Sept. 28	310	80	30	660	250	470	20	250	<10	10
29	6,000	600	20	42,000	2,700	6,000	700	3,200	2,300	<10
30	17,000	2,100	20	14,000	14,000	14,000	1,000	26,000	1,200	10
Gm	3,162	465	23	7,294	2,114	3,405	837	1,277	<302	<10
S.D.	22,089	1,955	6	55,450	13,884	16,516	1,259	26,873	-	-

TABLE XIII Continued

DATE SAMPLED	STATION NUMBER											
	067A	067B	067C	065B	065C	068A	069B	070A	070E	070B	070D	070C
Aug. 6	7,000	<10	≈10	2,800	<10	4,000	400	-	-		-	
7	80,000	2,000	1,100	≈5,000	1,300	30,000	1,400	≈10	-	4,000	-	≈100
8	120,000	20,000	800	8,000	1,100	30,000	1,100	-	-		-	
9	70,000	≈200	≈500	14,000	≈800	7,000	<100	≈100	-	1,500	-	≈900
Gm	46,571	≤532	≈258	≈6,293	≤327	12,599	<498	≈32	-	2,449	-	≈300
S.D.	121,600	-	-		-	22,604	-	-	-	-	-	-
Sept. 28	60	20	<10	10	10	200	<10	<10	110	100	30	≈40
29	10,000	400	10	800	<10	700	≈10	≈40	≈30	≈60	≈20	≈20
30	-	800	-	2,400	20	6,000	50	<10	1,100	1,900	200	220
Gm	775	186	<10	268	<13	944	<17	<16	≈154	≈225	≈49	≈56
S.D.	-	1,133	-	4,597	-	4,326	-	-	-	-	-	-

Gm = Geometric Mean
S.D. = Standard Deviation
- = No sample, no analysis, or S.D. could not be calculated
≈ = Approximately

TABLE XIV
FECAL STREPTOCOCCUS CONCENTRATIONS (organisms/100 mL) IN ST. LAWRENCE RIVER SURFACE WATERS (1.5 m depth) DURING 1982

DATE SAMPLED	STATION NUMBER										
	072B	066B	054A	054B	054C	056A	056B	058A	058B	058C	059A
Aug. 6	-	<100	<100	<100	<100	<100	<100	<100	<100	≈100	-
7	-	<100	<100	<100	<100	<100	<100	<100	<100	<100	-
8	-	<100	≈300	<100	≈800	≈100	<100	≈100	≈100	≈100	-
9	-	<100	<100	<100	<100	<100	<100	≈100	<100	<100	-
Gm	-	<100	≤132	<100	≤168	≤100	<100	≤100	≤100	≤100	-
S.D.	-	-	-	-	-	-	-	-	-	-	-
Sept. 28	<10	<10	<10	<10	<10	<10	<10	<10	≈10	<10	<10
29	<10	≈10	<10	<10	<10	≈50	<10	≈40	<10	<10	≈30
30	≈10	<10	<10	<10	<10	<10	<10	≈10	<10	<10	<10
Gm	≤10	≤10	<10	<10	<10	≤10	<10	≤10	≤10	≤10	
S.D.	-	-	-	-	-	-	-	-	-	-	-

TABLE XIV Continued

DATE SAMPLED	STATION NUMBER									
	060A	060B	060C	071A	071B	061A	061B	062A	062B	062C
Aug. 6	<100	-	-	-	-	-	<100	<100	<100	<100
7	<100	-	-	-	-	-	<100	≈100	<100	<100
8	<100	-	-	-	-	-	<100	≈100	<100	<100
9	≈200	-	-	-	-	-	<100	≈100	<100	<100
Gm	≤119	-	-	-	-	-	<100	≤100	<100	<100
S.D.	-	-	-	-	-	-	-	-	-	-
Sept. 28	≈10	<10	<10	≈40	≈10	≈20	<10	<10	<10	<10
29	≈10	≈10	<10	≈20	≈30	≈20	≈10	≈20	<10	<10
30	≈10	<10	<10	≈10	<10	≈20	<10	≈10	<10	<10
Gm	≈10	≤10	<10			≈20	≤10		<10	<10
S.D.	-	-	-	-	-	-	-	-	-	-

TABLE XIV Continued

DATE SAMPLED	STATION NUMBER											
	067A	067B	067C	065B	065C	068A	069A	070A	070E	070B	070D	070C
Aug. 6	<100	<100	<100	<100	<100	<100	<100	-	-	-	-	-
7	<100	<100	<100	<100	<100	<100	<100	<100	-	<100	-	<100
8	≈100	<100	<100	<100	<100	<100	<100	-	-	-	-	-
9	≈100	<100	<100	<100	<100	<100	<100	<100	-	≈200	-	<100
Gm	≤100	<100	<100	<100	<100	<100	<100	<100	-	≤141	-	<100
S.D.	-	-	-	-	-	-	-	-	-	-	-	-
Sept. 28	≈10	<10	<10	<10	<10	≈20	<10	<10	<10	<10	<10	≈10
29	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
30	-	<10	-	<10	<10	≈10	<10	≈10	≈10	<10	<10	<10
Gm	≤10	<10	<10	<10	<10		<10	≤10	≤10	<10	<10	≤10
S.D.	-	-	-	-	-	-	-	-	-	-	-	-

Gm = Geometric Mean
S.D. = Standard Deviation
≈ = Approximately

TABLE XV

Phenols Concentrations (ug/L) in St. Lawrence River Surface Waters (1.5 m depth) during 1980

Date Sampled	Station Number																				
	054A	054B	055	056A	056B	057	058	059	060	061A	061B	062A	062B	063A	063B	063C	064	065	066A	066B	002 (Grasse R)
July 24	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	<1
25	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	-
26	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	<1
x	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-	-	<1
S.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
July 29	16	8	-	13	7	6	5	4	-	2	1	3	1	2	1	1	1	1	-	-	2
30	23	11	10	10	6	5	4	3	2	2	1	2	1	2	2	<1	<1	1	-	-	-
31	11	13	12	2	7	6	6	6	5	5	3	5	4	5	4	2	3	3	-	-	17
x	16.7	10.7	11	8.3	6.7	5.7	5	4.3	3.5	3.0	1.7	3.3	2.0	3.0	2.3	<1.3	<1.7	1.7	-	-	9.5
S.D.	6.0	2.5	-	5.7	0.6	0.6	1	1.5	-	1.7	1.2	1.5	1.7	1.7	1.5	-	-	1.2	-	-	-
Sept. 9	7	2	3	5	3	4	3	3	2	3	<1	3	1	2	2	<1	1	1	-	-	1
10	9	3	3	6	3	5	3	4	3	2	<1	2	<1	2	2	<1	1	<1	-	-	-
11	6	3	6	5	4	3	3	2	2	1	1	1	1	1	1	<1	1	<1	-	-	1
x	7.3	2.7	4	5.3	3.3	4.0	3.0	3.0	2.3	2.0	<1	2	<1	1.7	1.7	<1	1	<1	-	-	1
S.D.	1.5	0.6	1.7	0.6	0.6	1.0	0	1.0	0.6	1.0	-	1	-	0.6	0.6	-	0	-	-	-	-
Oct. 21	13	7	8	11	6	5	5	5	3	3	1	3	3	3	2	2	3	2	-	-	<1
22	5	5	7	7	5	6	6	5	4	4	<1	3	1	4	3	1	3	1	-	-	-
23	7	5	7	7	5	3	3	2	2	2	<1	2	2	2	2	<1	1	1	-	-	<1
x	8.3	5.7	7.3	8.3	5.3	4.7	4.7	4.0	3.0	3.0	<1	2.7	2.0	3.0	2.3	<1.2	2.3	1.3	-	-	<1
S.D.	4.2	1.2	0.6	2.3	0.6	1.5	1.5	1.7	1.0	1.0	-	0.6	1.0	1.0	0.6	-	1.2	0.6	-	-	-
Nov. 25	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1
26	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	-
27	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1
x	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1
S.D.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Phenols laboratory detection limit = 1 ug/L

x = Mean

S.D. = Standard Deviation

- = No sample (or no S.D. calculated)

TABLE XVI
PARTICLE SIZE COMPOSITION (BY %) OF BOTTOM SEDIMENTS COLLECTED IN THE CORNWALL-MASSENA AREA OF THE ST. LAWRENCE RIVER - 1979

STATION NO.	CANADA/ USA.	WENTWORTH SIZE CLASS								DESCRIPTION
		GRAVEL	VERY COARSE SAND	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY	
		SIEVE NO.								
		10	18	35	60	120	230	BY DIFFERENCE	2 HOUR HYDROMETER METHOD	
		PARTICLE SIZE IN MM.								
		<4.75 >2.0	<2.0 >1.0	<1.0 >0.5	<0.5 >0.25	<0.25 >0.125	<0.125 >0.0625	<0.0625 >0.005	<0.005	
112	C	0.0	0.3	0.4	1.5	3.7	13.1	53.9	27.0	black reworked clay (2cm)
113	A	0.0	0.0	11.3	17.1	16.2	9.3	14.8	31.3	sand & clay (4cm)
111	A	12.8	8.6	0.2	0.9	9.9	17.8	21.8	28.0	clay (7cm)
110	A	1.1	0.6	1.0	2.7	8.7	10.7	69.1	6.1	grey clay & ooze (7cm)
109	C	-	-	-	-	-	-	-	-	
108	C	-	-	-	-	-	-	-	-	
107	C	-	-	-	-	-	-	-	-	
106	C	0.0	6.0	11.5	11.2	14.9	14.6	25.4	16.4	v. smelly, soft black ooze (10cm)
105	C	2.0	1.8	2.8	4.4	9.8	21.0	51.6	6.6	smelly, black ooze (10cm)
104	C	5.0	2.9	4.3	9.5	40.5	25.0	12.8	0.0	black silt + 50% wood chips (10cm)
103	C	2.8	2.5	5.1	17.9	22.8	17.3	23.5	8.1	dark grey, sandy clay (5cm)
102	C	-	-	-	-	-	-	-	-	
101	C	21.0	1.7	1.8	3.2	13.9	26.3	25.2	6.9	dark grey sand/silt/clay (10cm)
100	C	60.3	19.4	11.6	3.8	2.0	0.6	2.3	0.0	gravel/clay/sand (6cm)
099	C	-	-	-	-	-	-	-	-	
098	C	1.3	1.5	5.0	36.2	19.4	11.6	18.3	6.7	soft black ooze (7cm)
097	C	-	-	-	-	-	-	-	-	
096	C	-	-	-	-	-	-	-	-	
095	C	0.0	0.9	1.8	6.2	13.5	19.1	52.0	6.5	black ooze; strong oily smell(9cm)
094	C	3.8	2.0	9.0	17.7	11.4	9.2	33.2	13.7	black sand & ooze (10cm)
093	C	0.0	0.4	1.4	4.6	12.7	32.2	48.7	0.0	black ooze

TABLE XVI Continued

STATION NO.	CANADA/ USA.	WENTWORTH SIZE CLASS								DESCRIPTION
		GRAVEL	VERY COARSE SAND	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY	
		SIEVE NO.								
		10	18	35	60	120	230	BY DIFFERENCE	2 HOUR HYDROMETER METHOD	
		PARTICLE SIZE IN MM.								
		<4.75 >2.0	<2.0 >1.0	<1.0 >0.5	<0.5 >0.25	<0.25 >0.125	<0.125 >0.0625	<0.0625 >0.005	<0.005	
092	C	1.3	0.4	2.5	3.4	14.1	10.0	55.3	13.0	black ooze (8cm)
091	C	0.6	0.8	2.2	3.9	23.3	40.9	26.2	2.1	black silt + upper brown oxide layer
090	C	6.0	2.7	1.4	4.0	12.3	21.7	45.0	6.9	black sandy clay (7cm)
089	C	1.5	0.9	0.7	0.9	2.7	9.4	80.0	3.9	black sandy ooze (10cm)
088	C	2.0	2.3	2.4	8.1	19.8	18.1	40.5	6.8	black ooze (10cm)
087	C	0.5	0.3	0.5	5.9	10.7	21.6	53.1	7.4	black sandy clay (10cm)
086	A	0.0	0.0	0.1	0.3	2.2	6.6	74.8	16.0	black ooze;upper oxidized layer(9cm)
085	A	0.9	0.7	0.8	1.6	3.3	6.4	44.4	41.9	grey silty ooze;upper oxidized layer (10cm)
084	A	0.0	0.7	1.1	1.9	6.3	23.6	49.6	16.8	black ooze; upper oxidized layer brown (11cm)
083	A	18.0	1.1	1.8	1.0	7.6	16.9	47.0	6.6	black oily sand (7cm)
082	A	0.0	0.4	0.5	1.2	8.3	19.8	43.7	26.1	black ooze; upper oxidized layer (8.5cm)
081	C	0.0	0.5	0.4	2.1	30.4	39.6	20.3	6.7	grey clay + sand (4.5cm)
080	C	5.2	1.2	1.1	2.4	33.5	31.7	15.3	9.6	grey clay; upper oxidized
079	A	4.8	2.6	2.3	6.5	13.8	15.8	36.3	17.9	clay + silt (3cm)
078	A	2.4	2.2	12.6	71.8	9.4	0.6	1.0	0.0	sand (8cm)
077	A	0.7	0.8	1.5	3.3	59.0	12.1	8.0	14.6	black ooze (9cm)
076	A	0.0	0.5	1.0	2.6	16.7	35.9	33.2	10.1	black ooze (9cm)
075	A	4.1	1.8	3.1	8.3	11.3	22.8	39.3	9.3	sandy silt (3cm)
074	A	-	-	-	-	-	-	-	-	
073	A	0.0	0.2	0.3	9.4	72.7	12.2	5.2	0.0	sand (4cm)
072	A	0.0	2.2	1.2	1.6	5.0	25.7	55.7	8.6	black ooze (5cm)

TABLE XVI Continued

STATION NO.	CANADA/ USA.	WENTWORTH SIZE CLASS								DESCRIPTION
		GRAVEL	VERY COARSE SAND	COARSE SAND	MEDIUM SAND	FINE SAND	VERY FINE SAND	SILT	CLAY	
		SIEVE NO.								
		10	18	35	60	120	230	BY DIFFERENCE	2 HOUR HYDROMETER METHOD	
		PARTICLE SIZE IN MM.								
		<4.75 >2.0	<2.0 >1.0	<1.0 >0.5	<0.5 >0.25	<0.25 >0.125	<0.125 >0.0625	<0.0625 >0.005	<0.005	
071	C	0.6	0.8	2.4	3.3	13.4	19.2	58.0	2.3	black silty ooze; clay; organic matter (8cm)
070	C	12.5	7.7	14.6	31.6	13.6	6.4	5.6	8.0	black silt & sand (6cm)
069	C	2.0	3.8	10.8	37.7	25.0	9.8	4.1	6.8	black silty sand (2.5cm)
068	C	0.0	0.0	4.0	53.8	39.7	1.6	0.9	0.0	coarse sand + organic litter (9cm)
067	C	0.0	0.4	0.7	11.1	60.1	3.8	10.1	13.8	clay + sand (5cm)
066	C	0.0	2.9	5.0	4.8	11.9	18.8	49.2	7.4	black ooze (9cm)
065	C	0.0	0.9	2.2	4.0	21.2	30.8	26.1	14.8	black ooze (9.5cm); upper brown oxide (0.5cm)
064	C	0.0	0.9	0.5	2.0	11.0	25.0	53.3	7.3	black ooze (10cm); upper brown oxide (2.5cm)
063	C	0.9	1.1	6.2	30.7	34.7	14.5	10.7	1.2	black clay (6.5cm)
062	C	4.8	1.4	1.5	8.1	12.2	16.7	46.8	8.5	black sandy clay (5cm)
061	C	2.4	3.2	15.9	43.9	16.7	8.5	7.3	2.1	black sand & silt (7cm)
060	C	0.5	6.6	35.0	48.0	6.6	0.9	0.4	2.0	sand (9cm)
059	C	1.2	0.4	0.8	1.6	28.5	5.3	35.0	27.2	grey sandy clay (7cm)
058	C	0.0	0.6	1.4	8.0	13.6	27.7	48.7	0.0	sand & silt (8cm)
057	C	6.5	3.1	11.8	10.6	11.7	11.4	36.9	8.0	sand & silt (6cm)
056	C	1.9	0.3	0.9	1.2	4.9	21.4	68.0	1.4	sand & silt (6cm)
055	C	2.2	1.1	3.7	6.7	10.3	16.6	54.1	5.3	silt & organic litter
035	A	0.6	1.5	1.0	1.9	2.5	5.5	73.3	13.7	v. black, silty clay (8.5cm)
033	A	1.2	2.5	6.3	16.6	18.7	12.6	34.8	7.3	soft silty clay (7.5cm)
004	A	8.5	10.1	22.5	43.7	11.6	1.2	2.4	0.0	sand (2cm)
003	A	5.5	2.4	4.4	7.4	21.9	27.2	31.2	0.0	silt, wood chips & organic debris
002	A	0.0	0.3	0.1	0.4	1.7	7.2	71.5	18.8	black ooze;upper oxidized layer(8cm)

TABLE XVII
CONTAMINANTS CONCENTRATIONS IN BIOTA FROM THE CORNWALL-MASSENA AREA, 1979

STN	TAXONOMIC GROUP	ORGANISM	µg/g, wet weight								ng/g, wet weight													
			Aluminum	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Zinc	PCBs	Dieldrin	α-BHC	β-BHC	γ-BHC	α-Chlordane	γ-Chlordane	p,p'-DDT	p,p'-DDD	p,p'-DDE	Endrin	HCB	Thiodan II	2,4,6-Trichlorophenol	Pentachlorophenol
112	Chlorophyta	Cladophora glomerata	8900	<0.2	7.4	16	4200	6.8	-	81	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Spermatophyta	Myriophyllum exalbescens	5200	<0.3	2.5	23	2800	7.0	-	59	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	"	Typha angustifolia	510	<0.1	< 0.5	3.1	7	1.1	-	10	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Amphipoda	Gammarus pseudolimnaeus	3700	<2.0	8.9	68	950	<9.0	-	78	24	1	ND	ND	ND	2	ND	ND	ND	ND	2	ND	1	ND	ND
104	Spermatophyta	Myriophyllum exalbescens	2800	<1.0	6.7	25	2000	<5.9	0.04	66	ND	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	"	Potamogeton pectinatus	1000	1.2	4.8	14	860	5.0	0.12	84	ND	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	"	Typha alternifolia	<3.6	<0.9	<3.7	<1.8	<4.5	<5.4	0.08	8.8	ND	-	-	-	-	-	-	-	-	-	-	-	-	50	ND
	Gastropoda	Bulimus tentaculatus/ Gyraulus deflectus	114	<0.5	2.6	59	510	<3.2	<0.01	32	20	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	"	Ferrissia parallela/ Lymnaea sp.	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pelecypoda	Elliptio complanata	-	-	-	-	-	-	-	-	68	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Oligochaeta	Limnodrilus sp. (imm.)	-	-	-	-	-	-	-	-	35	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Hirudinea	Helobdella fusca	-	-	-	-	-	-	-	-	150	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Amphipoda	Gammarus pseudolimnaeus	-	-	-	-	-	-	-	-	ND	-	-	-	-	-	-	-	-	-	-	-	-	-	-
095	Chlorophyta	Cladophora glomerata	1700	<1.0	20	45	1900	<5.9	0.28	450	ND	-	-	-	-	-	-	-	-	-	-	-	-	50	80
	Spermatophyta	Elodea canadensis	510	<1.0	15	18	930	<6.3	0.19	365	ND	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	"	Myriophyllum exalbescens	2200	<0.9	28	53	2700	13	0.29	560	ND	-	-	-	-	-	-	-	-	-	-	-	-	50	50
	"	Scirpus validus	380	<0.6	<2.2	4	135	<3.3	0.06	30	ND	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Turbelaria	Flatworm, unidentified	-	-	-	-	-	-	-	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Gastropoda	Gyraulus parvus	595	<0.4	4.5	36	660	12	0.05	150	ND	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	"	Lymnaea sp.	-	-	-	-	-	-	-	-	ND	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	"	Bulimus tentaculatus/ Physa sp./Helisoma pilsbryi	-	-	-	-	-	-	-	-	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Amphipoda	Gammarus lacustris/ G. pseudolimnaeus	-	-	-	-	-	-	-	-	45	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE XVII Continued

STN	TAXONOMIC GROUP	ORGANISM	µg/g, wet weight								ng/g, wet weight														
			Aluminum	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Zinc	PCBs	Dieldrin	α-BHC	β-BHC	γ-BHC	α-Chlordane	γ-Chlordane	p,p'-DDT	p,p'-DDD	p,p'-DDE	Endrin	HCB	Thiodan II	2,4,6-Trichlorophenol	Pentachlorophenol
071	Spermatophyta	Ceratophyllum demersum	1300	<0.8	4.1	12	3500	5.9	0.09	790	ND	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	"	Myriophyllum exalbescens	520	<0.5	2.4	9.2	540	<3.2	0.03	160	ND	-	-	-	-	-	-	-	-	-	-	-	-	50	90
	"	Vallisnaria americana	130	<0.7	4.6	8.0	330	6.8	0.02	430	ND	-	-	-	-	-	-	-	-	-	-	-	-	50	60
	Gastropoda	Amnicola/Bulimus tentaculatus/Physa sp./ Gyraulus parvus	285	<0.4	<1.8	59	455	<2.7	<0.01	49	ND	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	Hirudinea	Batracobdella phalera/ Helobdella fusca/ H. lineata/H. stagnalis	-	-	-	-	-	-	-	-	180	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Isopoda	Asellus sp.	-	-	-	-	-	-	-	-	39	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Amphipoda	Gammarus pseudolimnaeus	-	-	-	-	-	-	0.68	-	29	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
055	Spermatophyta	Alisma gramineum	-	<1.0	6.8	3.9	-	<5.8	0.02	30	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
	"	Ceratophyllum demersum	-	<1.0	<4.2	7.3	-	12	0.25	150	20	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
	"	Nuphar luteum	-	<0.8	<5.0	5.6	-	<5.0	<0.01	22	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
	"	Vallisneria americana	-	<0.9	6.9	5.2	-	<5.1	0.02	72	ND	ND	1	ND	1	ND	ND	ND	ND	ND	ND	1	ND	-	-
	"	Potamogeton pectinatus	-	<1.1	8.0	3.4	-	<6.8	0.02	70	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
	Pelecypoda	Clams, unidentified	-	-	-	-	-	-	-	-	20	1	3	ND	1	2	1	ND	5	ND	ND	ND	ND	-	-
033	Spermatophyta	Elodea canadensis	2000	<0.3	<1.3	34	910	5.9	-	100	74	ND	ND	7	3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	"	Myriophyllum exalbescens	2600	<0.2	5.8	23	1800	4.0	-	86	ND	ND	1	ND	6	ND	ND	ND	ND	ND	ND	ND	ND	ND	100
	"	Typha alternifolia	810	<0.2	<0.6	4.4	66	3.0	-	19	ND	ND	ND	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND
	"	Vallisneria americana	3800	<0.4	<5.0	9.5	2400	6.8	-	240	-	-	-	-	-	-	-	-	-	-	-	-	-	ND	110
	Gastropoda	Amnicola sp./Bulimus tentaculatus/ Probythinella lacustris/ Physa sp./Gyraulus parvus/Valvata sincera/ Votricarinata	-	-	-	-	-	-	-	-	82	ND	ND	ND	ND	ND	1	ND	ND	2	ND	ND	ND	ND	ND

TABLE XVII Continued

STN	TAXONOMIC GROUP	ORGANISM	µg/g, wet weight								ng/g, wet weight														
			Aluminum	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Zinc	PCBs	Dieldrin	α-BHC	β-BHC	γ-BHC	α-Chlordane	γ-Chlordane	p,p'-DDT	p,p'-DDD	p,p'-DDE	Endrin	HCB	Thiodan II	2,4,6-Trichlorophenol	Pentachlorophenol
033 Ctd	Gastropoda	Amnicola sp./Ferrissia parallela/Physa sp./ Gyraulus deflectus/ G. parvus/ Helisoma pilsbryi	180	<0.2	1.2	65	18	2.2	-	46	300	ND	ND	ND	4	13	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Pelecypoda	Elliptio complanata/ Lampsilis radiata	1100	<0.1	<0.8	4.8	225	1.2	-	100	-	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	"	Sphaerium sp.	-	-	-	-	-	-	-	-	130	ND	2	ND	4	1	1	5	ND	11	ND	ND	ND	-	-
	Amphipoda	Hyalella azteca	-	-	-	-	-	-	-	-	120	6	13	ND	20	ND	ND	ND	ND	4	ND	1	ND	-	-
003	Spermatophyta	Elodea canadensis	1600	1.0	<1.7	8.4	1400	5.3	-	200	-	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	"	Nuphar luteum	960	<0.2	0.9	3.0	400	<0.9	-	35	-	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	"	Pontederia cordata	950	<0.2	<0.8	4.5	350	10	-	34	-	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	"	Typha alternifolia	720	<0.3	<1.1	2.0	680	2.6	-	24	-	-	-	-	-	-	-	-	-	-	-	-	-	ND	ND
	"	Vallisneria americana	3160	0.6	<1.3	15	2100	4.0	-	110	ND	ND	3	ND	5	1	ND	ND	10	ND	ND	ND	ND	ND	ND
	Gastropoda	Amnicola sp./ Gyraulus parvus/ Helisoma trivolvis	-	-	-	-	-	-	-	-	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	-	-
	"	Amnicola sp./ Bulimus tentaculatus/ Physa sp./ Gyraulus deflectus/ G. parvus	-	-	-	-	-	-	-	-	55	ND	5	ND	ND	ND	ND	ND	3	ND	ND	ND	ND	-	-
	Pelecypoda	Pisidium sp.	2900	1.7	1.8	14	730	<1.0	-	320	585	2	10	ND	5	ND	ND	ND	ND	10	ND	ND	ND	-	-
	Hirudinea	Batracobdella phalera	-	-	-	-	-	-	-	-	1030	2	10	ND	30	ND	ND	ND	10	10	ND	ND	ND	-	-
	Diptera	Tendipes s.l.	-	-	-	-	-	-	-	-	250	2	10	ND	15	ND	ND	ND	5	5	ND	ND	ND	-	-
	Ephemeroptera	Hexagenia sp.	-	-	-	-	-	-	-	-	235	ND	3	ND	ND	ND	ND	ND	ND	10	ND	ND	ND	-	-
	Coleoptera	Dubiraphia bivittata	10700	<1.6	<6.5	25	6900	19	-	280	20	2	5	ND	ND	ND	ND	ND	ND	5	ND	ND	ND	-	-
	Amphipoda	Gammarus lacustris	-	-	-	-	-	-	-	-	145	3	10	ND	20	ND	ND	ND	30	5	ND	ND	ND	-	-

TABLE XVII Continued

STN	TAXONOMIC GROUP	ORGANISM	µg/g, wet weight								ng/g, wet weight														
			Aluminum	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Zinc	PCBs	Dieldrin	α-BHC	β-BHC	γ-BHC	α-Chlordane	γ-Chlordane	p,p'-DDT	p,p'-DDD	p,p'-DDE	Endrin	HCB	Thiodan II	2,4,6-Trichlorophenol	Pentachlorophenol
068	Spermatophyta	Elodea canadensis	2700	0.8	<2.6	5.9	1100	<0.4	-	96	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	"	Eleocharis sp.	800	<0.2	<0.8	4.3	230	1.6	-	32	ND	ND	2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	100
	"	Myriophyllum exalbescens	2000	0.4	<1.3	5.8	3400	3.6	-	130	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	110
	"	Typha alternifolia	1000	<0.3	<1.2	2.5	73	1.9	-	16	ND	ND	1	ND	ND	1	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Gastropoda	Amnicola sp./Sematogyrus subglobosus/Physa sp./ Gyraulus parvus	980	<0.8	<3.4	17	340	<5.1	-	51	36	2	ND	ND	ND	2	1	ND	ND	3	ND	2	ND	ND	ND
	"	Ferrissia parallela/ Gyraulus parvus	2000	<0.8	<3.1	29	340	<4.7	-	30	110	ND	ND	ND	ND	2	ND	ND	ND	5	2	1	ND	ND	ND
	Pelecypoda	Elliptio complanata	2500	0.6	2.3	13	1100	<2.2	-	120	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Amphipoda	Gammarus/acustris/ G. pseudolimnaeus/ Hyalella azteca	2200	0.8	<2.5	57	250	<3.8	-	91	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

ND = not detected
"-" = not available

NOTE: 1) Other organochlorines and chlorophenols analyzed for but not found in any samples include:
- Heptachlor, Heptachlor epoxide, Aldrin, Thiodan (Endosulfan) I, o,p'-DDT and Mirex
- 2,4-D, 2,4-DB, 2,4,5-T, Silvex, 2,3,4-Trichlorophenol, 2,4,5-Trichlorophenol.

TABLE XVIII
CURRENT SPEED (cm sec^{-1}) AND DIRECTION (degrees from North)
OF ST. LAWRENCE RIVER SURFACE WATERS (1.5 m depth)
DURING 1982 AUGUST SURVEY.

DATE	STATION NUMBER					
	058A	058B	058C	067A	067B	067C
Aug. 6	84.2 ± 2.7 (77°)	125.9 ± 4.1 (77°)	53.1 ± 5.4 (100°)	55.6 ± 1.1 (78°)	63.9 ± 2.8 (80°)	109.8 ± 2.3 (30°)
Aug. 7	86.6 ± 3.9 (90°)	107.2 ± 3.9 (87°)	36.4 ± 6.8 (100°)	58.7 ± 2.6 (78°)	62.1 ± 2.7 (55°)	101.2 ± 3.8 (30°)
Aug. 8	86.6 ± 6.3 (90°)	102.6 ± 7.5 (86°)	134.6 ± 7.2 (97°)	58.2 ± 3.4 (78°)	60.4 ± 8.3 (75°)	103.8 ± 7.2 (30°)
Aug. 9	90.1 ± 4.1 (90°)	131.1 ± 11.5 (88°)	117.0 ± 5.1 (96°)	56.9 ± 5.1 (70°)	65.7 ± 2.2 (66°)	120.1 ± 4.8 (35°)
Sept. 28	84.5 ± 1.7 (87°)	98.4 ± 2.3 (86°)	143.2 ± 9.6 (93°)	37.6 ± 3.3 (80°)	52.8 ± 3.9 (55°)	98.4 ± 2.3 (30°)
Sept. 29	77.0 ± 2.8 (88°)	107.3 ± 5.4 (89°)	111.3 ± 5.8 (92°)	46.9 ± 1.0 (82°)	51.7 ± 1.2 (56°)	87.1 ± 5.4 (30°)
Sept. 30	80.7 ± 10.6 (86°)	90.9 ± 0.0 (88°)	144.2 ± 19.4 (90°)	44.8 ± 0.0 (82°)	50.9 ± 1.2 (56°)	93.8 ± 4.1 (32°)
Study x	84.2 (87°)	109.0 (88°)	105.7 (95°)	51.2 (78°)	58.2 (63°)	102.0 (31°)

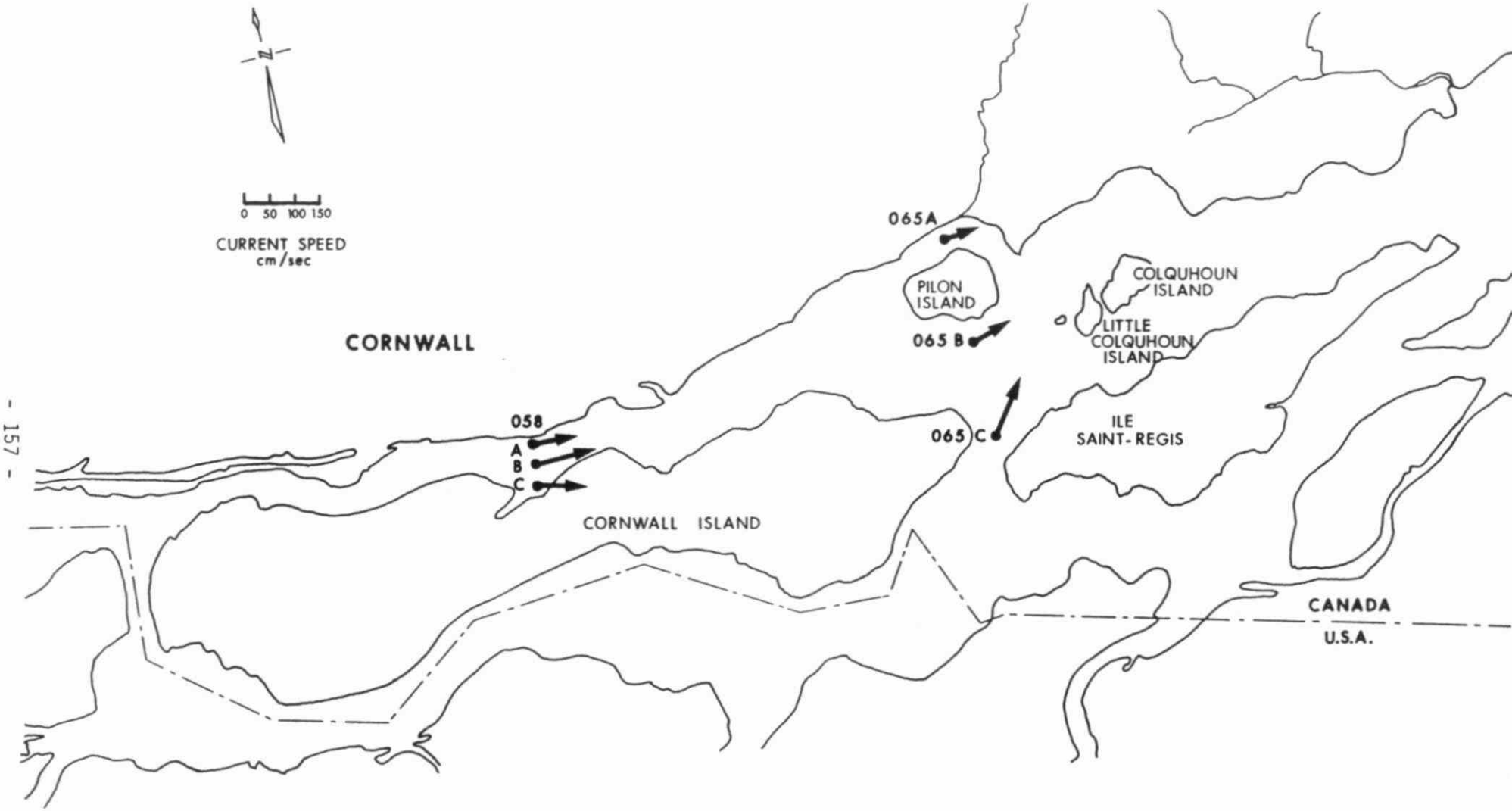

Figure I. Mean Current Speed and Direction (1.5m depth) during August 6-9, 1982 Survey.